Estimates of the stilling basin residence time and lateral distribution of juvenile Chinook salmon passing through the spillway at The Dalles Dam during 2002

Final Report of Research during 2002

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Summary

In 2002, the U.S. Army Corps of Engineers (COE) contracted with the U.S. Geological Survey to determine the stilling basin residence time and lateral distribution of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) passing through the spillway at The Dalles Dam (TDA). The objective was to estimate the residence time and lateral distribution of passage through the stilling basin of fish released through each of three spill bays. This information will be used to characterize stilling basin egress times, identify paths taken by fish passing through each of the three spill bays, and serve as explanatory information for survival studies (Counihan et al. In Review; Normandeau Associates, 2003).

Monitoring system: Separate aerial and underwater telemetry systems were used to detect tagged fish traveling through the stilling basin. The aerial antenna system was designed to detect fish between the spillway and the end sill. The underwater antenna system was designed to detect fish passing within 25 m of the end sill.

Dam Operations: During the hours of spring fish releases, from 01 May to 01 June, the mean total project discharge was 244 thousand cubic feet/second (KCFS), the mean spill discharge was 87 KCFS (36% of total project discharge) and the mean tailwater elevation was 81.2 ft. The mean total project discharge for the hours of the summer fish releases (02 July through 22 July) was 235 KCFS, mean spill discharge was 95 KCFS (40% of the total project discharge) and the mean tailwater elevation was 80.3 ft.

Number of Fish Released and Detected: From 01 May to 01 June 2002, we released 943 yearling Chinook salmon through spill bays 4, 9, and 13. The aerial antenna array detected 70% of the released fish and the underwater array detected 9%. Summer releases were conducted 01 July through 22 July 2002 during which time 911 subyearling Chinook salmon were released through spill bays 4 and 13. The aerial antenna array detected 95% of the released fish and the underwater array detected 8%.

Lateral Distribution within the Stilling Basin: Most fish released from spill bay 13 moved north laterally in the stilling basin based upon their last detected location. Based on aerial array detections of fish released from spill bay 13, 84% of yearling Chinook salmon and 85% of subyearling Chinook salmon were last detected downstream of the area between bays 11 and 2. Fish released through spill bay 9 also moved north laterally, with 51% of yearling Chinook salmon last detected downstream between bays 7 and 2; fish were only released from bay 9 during the spring. The percentage of fish detected from the spill bay 4 releases that moved north laterally was 51% during the spring and 47% during the summer.

Stilling Basin Residence Times: Residence times of fish that exited directly from the stilling basin were shorter than fish that moved laterally in the stilling basin. For example, yearling Chinook salmon released from bay 13 that had direct egress paths through the stilling basin had a median residence time of 0.9 min (range 0.6 to 21.2 min, N = 30), whereas those with northward lateral movement had a median time of 3.3 min (range 1.3 to 10.1 min, N = 32). Similarly, residence times of subyearling Chinook salmon released from bay 13 that had direct egress paths through the stilling basin had a median residence time of 1.4 min (range 0.1 to 19.6 min, *N* = 16) and those that moved laterally northward had a median residence time of 3.0 min (range 1.2 to 36.5 min, *N* = 42).

Drogue Releases: A total of 83 drogues were released at spill bays 4, 9 and 13 between 05 May and 07 August 2002. Overall, 75% of drogues traveled laterally at least one bay and 23% were transported laterally at least four bays. All lateral movement of drogues occurred between the base of the spillway ogee and the baffle blocks. Drogues released from bay 13 showed the highest proportion of lateral movement (100%). Drogues released from the other bays also moved laterally, with 71% of those released from bay 9 and 53% of those from bay 4 moving northward at least one bay. The median travel time of drogues released at bay 13 (4.1 min) was greater than drogues released at bay 9 (2.9 min) or bay 4 (3.1 min). Due to a large variation in spill discharge, total project discharge, and tailwater elevation between release dates, no statistical comparisons of data from drogues were made.

Introduction

Recent studies have suggested that the relative survival rates of juvenile Chinook salmon passing through the spillway of The Dalles Dam (TDA) are lower than at most other dams on the Columbia and Snake rivers (Counihan et al. 2002). The exact mechanism leading to lower survival is not known, although several explanations have been proposed.

One possible explanation for the low survival may be extended residence times in the stilling basin and/or increased injury of fish passing through the stilling basin in the lateral flow created by the juvenile spill pattern. The juvenile spill pattern is designed to avoid passing fish through the southern portion of the spillway to reduce the likelihood of entering the shallow areas and islands in the southern tailrace. In an effort to prevent fish passage through these areas, proportionally more water is spilled through the northern spill bays than southern spill bays. One consequence of the juvenile spill pattern is the formation of northward lateral movement of water in the stilling basin area.

This study was designed to determine if fish are entrained in the northward flow in the stilling basin created by the juvenile spill pattern, and to quantify movements in terms of distance and effect on residence time with in the stilling basin. In 2001, an underwater detection system was designed and installed in the stilling basin to act as an exit array with which to determine the lateral distribution and residence time of fish exiting the stilling basin. The underwater system sustained structural damage during the 2001 spill season, so the array was removed and a redesigned array was installed prior to the 2002 research season. The new design incorporated several modifications to the dipole antennas and associated wiring to better withstand the hydraulic forces in the stilling basin (Beeman et al. 2004).

Methods

Study site

The Dalles Dam is located on the Columbia River at river km 307 (Figure 1). The dam consists of a single powerhouse of 22 turbine units and a single spillway of 23 tainter gates. The powerhouse is oriented parallel to river flow, whereas the spillway is perpendicular to river flow. A non-overflow wall oriented parallel to river flow connects the powerhouse and spillway. A navigation lock is located at the north end of the dam.

Radio Transmitters and Fixed Receiving Equipment

Pulse-coded transmitters were implanted in yearling and subyearling Chinook salmon allowing each individual fish to be uniquely identified. The radio transmitters used in the spring were Lotek Wireless model MCFT-3KM with 30 cm ‘Sava’ antenna (Lotek Wireless, Newmarket, Ontario, Canada[1]), which were 7.3 mm (diameter) X 18 mm and weighed 1.4 g in air, and 0.8 g in water. The transmitters used in the summer were Lotek Wireless model NTC-3-1 with 30 cm ‘Sava’ antenna, which were 6.3 mm (width) X 4.5 mm (height) X 14.5 mm and weighed 0.85 g in air, and 0.50 g in water.

[1] Use of trade names does not imply endorsement by the U. S. Government.

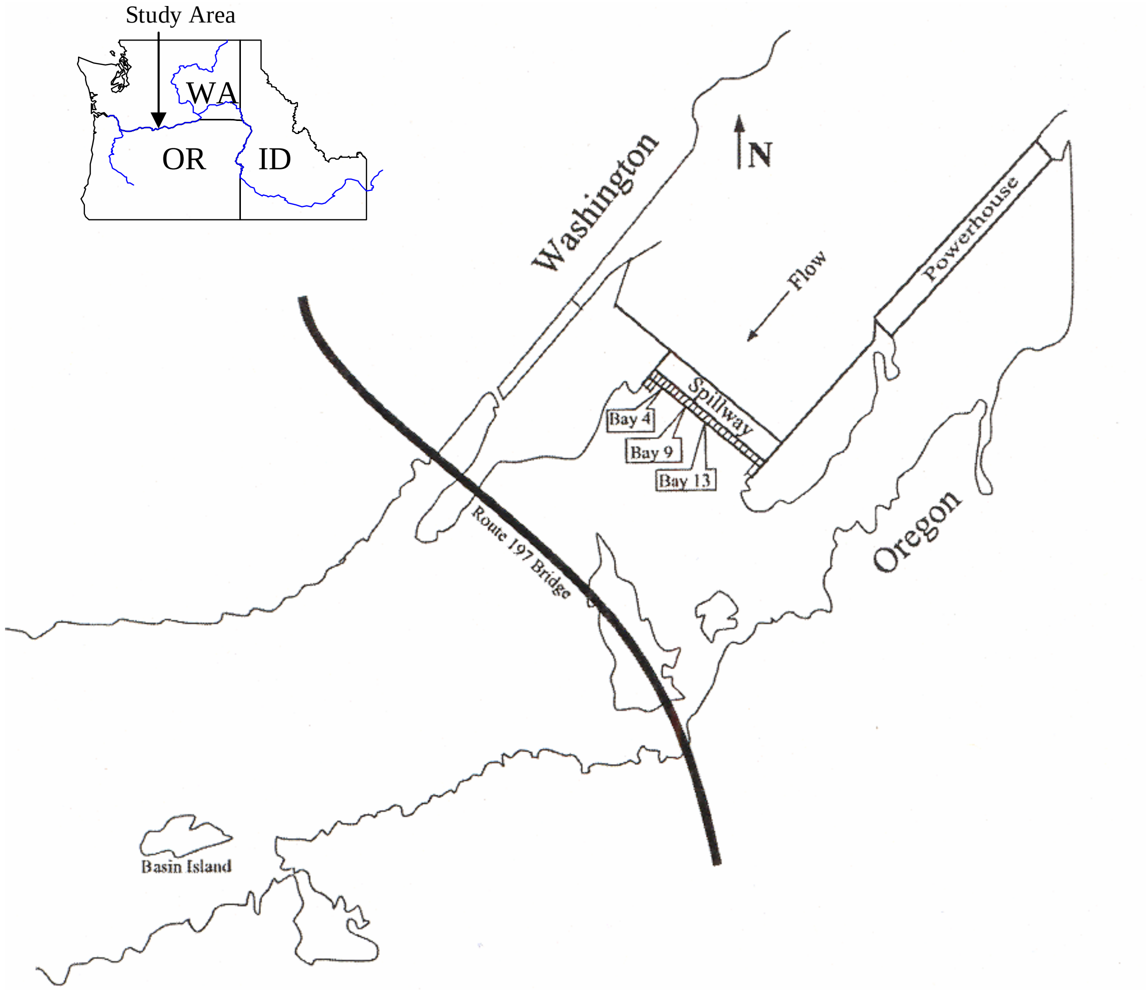

Figure 1. The Dalles Dam (river km 307) study site on the Columbia River and map indicating study site relative to the States of Washington (WA), Oregon (OR), and Idaho (ID).

The frequency range of the transmitters was between 150.280 and 150.760 MHz. The underwater antenna array consisted of two parallel arrays of 46 half-wavelength armored dipole antennas each, providing a combined coverage area of approximately 25 m along the end sill from spill bays 1 through 23. The underwater antenna array was monitored by a Multiprotocol Integrated Telemetry Acquisition System (MITAS; Grant Systems Engineering, King City, Ontario, Canada). The area of coverage was expanded from the prototype system installed in 2001, which monitored spill bays 1 through 16. Armored dipole antennas were mounted on a steel plate with a debris deflector to protect the antenna housing against impact from suspended materials (Figure 2). The placement of underwater antennas relative to the stilling basin and end sill are indicated in Figure 3.

Figure 2. Example of an armored dipole antenna and steel debris deflector plate used in the underwater antenna array at The Dalles Dam stilling basin in 2002. The dipole antenna is mounted underneath the 12.7 cm inside diameter PVC cap with the antenna elements oriented as indicated by the lines on the cap.

The aerial antenna array consisted of twelve 22-element corner reflector antennas (Figure 4). This antenna type has a radiation pattern with reduced side and back lobes compared to Yagi antennas, and were used to reduce the effects of ambient radio noise known to exist in the tailrace of TDA. Mounted on the railing of the pier nose platform, the antennas were directed downward approximately 30 degrees and toward the north shore approximately 30 degrees. Antennas were positioned in this manner to better cover the stilling basin area between the ogee and the end sill. The spillway aerial array was monitored by a second MITAS. The aerial antenna mounting locations were unchanged from the 2001 aerial system (Beeman et al. 2003).

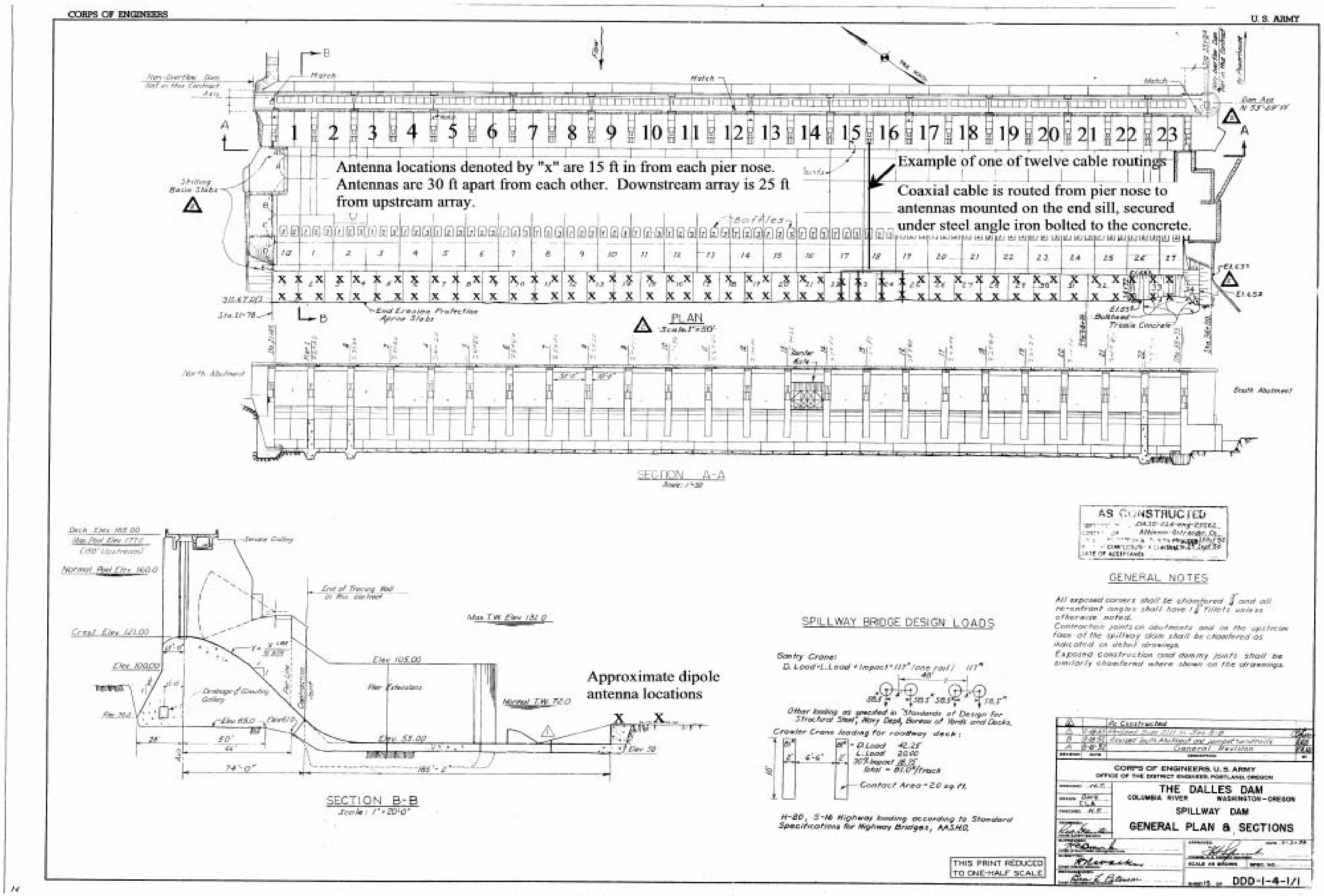

Figure 3. Schematic of The Dalles Dam stilling basin indicating locations of underwater antennas (X). Original schematic courtesy of the U.S. Army Corps of Engineers.

Figure 4. Photo of corner reflector antennas used in the aerial antenna array at The Dalles Dam stilling basin during 2002. The state of Washington can be seen in the background.

Fish Tagging, Handling, and Release

Yearling and subyearling Chinook salmon to be implanted with radio transmitters were obtained from the juvenile collection and bypass facility at John Day Dam. Fish were transported, via truck, to TDA and held about 24 h prior to tagging to allow for gut evacuation. Fish were considered suitable for tagging if they were free of injuries, severe descaling, external signs of gas bubble trauma, or other obvious abnormalities. Additionally, fish found to have passive integrated transponder (PIT) tags, elastomer tags, or other visible external tags were excluded from our research. Transmitters were gastrically implanted following the methods of Martinelli et al. (1998). Following tagging, fish were held in recovery tanks at TDA for about 24 h. Tagged fish were transported to the spill bays for release after each holding tank was checked for mortalities and regurgitated tags.

Release tanks were installed along the parapet wall on the spillway deck at spill bays 4, 9, 11, and 13. Placement of release tanks at spill bays 9, 11, and 13 allowed fish to be released near the southern edge of the spill pattern during various spill conditions. Normandeau Associates (2003) provides a detailed description of the release mechanism. Each release tank was supplied with water from the forebay via a submersible pump at a rate of approximately 200 L/min. Prior to placing fish into the release tanks, the tanks were filled until water flowed through the release hose to eliminate air pockets in the release mechanism. The fish were released from the tank by removing a standpipe, allowing the fish to discharge with the water volume of the tank. A 10 cm diameter release hose was connected to the lower end of the release tank, and the hose was extended through an opening on the spillway deck then routed to the center of the spill bay. One or two radio-tagged fish were placed into release tanks at spill bays 4, 9, and 13 (no fish were released through bay 9 during the summer) and were released simultaneously, whenever possible. Water from the submersible pump was flushed through tanks and hoses to ensure the fish exited the hose. The design allowed us to simulate fish passing the TDA spillway via a northern and southern route during the same flow conditions.

Drogue Releases

Aluminum drift buoys (drogues) were used to study the large-scale hydraulic trends encountered by juvenile salmon in the TDA spillway between 5 May and 7 August 2002 using methods described in Liedtke et al. (1999). Drogues were released on the ogee crest of spill bays 4, 9, and 13 during the spring study period (Figure 1), and at spill bays 4 and 13 during the summer study period.

Drogues were equipped with Global Positioning System (GPS) units, which collected spatial data as they drifted through the tailrace. The hydraulic environment at the base of the spillway is very turbulent, and drogues were often submerged for a short period of time. No spatial data were recorded during these periods because GPS signals are not received underwater. Thus, visual observations were recorded to describe drogue paths in turbulent areas. Boats were used to verify drogue positions and to retrieve drogues at the Basin Island (1.6 km downstream from the dam).

Data Management and Analysis

Data from the MITAS were typically downloaded every other day and were imported into SAS (version 8; SAS Institute Inc., Cary, N.C., USA) for proofing and analyses. Proofing eliminated non-valid records including background noise, single records of a particular channel and code, and records that were collected prior to the known release date and time.

Residence time in the stilling basin area was defined as the amount of time between release and last detection in the stilling basin by the aerial antenna system. In assigning an area of last detection by the aerial array it is common for radio-tagged fish to be detected on multiple aerial antennas at the same instance since the zones of coverage often overlap. To assign a last detection location, the detection with the highest signal strength was considered the best estimate of last location. Because antennas were angled to the north approximately 30 degrees, the detection range of each antenna overlapped into one or more spill bays to the north. Therefore, fish were probably further north in the stilling basin than the last assigned antenna location. Median stilling basin residence times of groups of fish released at the spill bays 4, 9, and 13 were compared statistically using a 2-way ANOVA. To account for possible diel variation, the day and night releases were analyzed separately. We chose the 2-way ANOVA as our analytical tool because it allowed us to determine whether interactions existed between release sites and release dates. Because the data was skewed, we transformed the mean residence times using the log transformation ($x=\log(x+1)$) to attain a more normal distribution. The dependent variable was log residence time and the independent variables were release bay, release date, and their interaction term. Results were considered statistically significant when $P < 0.05$. To determine which release sites were different during day releases we used a Ryan-Einot-Gabriel-Welsch (REGW) multiple range test.

Drogue travel times were calculated from the time of release to the time of arrival at the Highway 197 Bridge and at the Basin Island (Figure 1). Due to a large variation in spill discharge, total project discharge, and tailwater elevation between release dates, no statistical comparisons of data from drogues were made.

Results

Dam Operations

During the spring release period (01 May to 01 June) mean percent spill discharge, during the hours of release, was 87 KCFS (range 50 to 107 KCFS), mean total project discharge was 244 KCFS (range 134 to 314 KCFS), mean percent spill of the total project discharge was 36% (range 24 to 42%) and mean tailwater elevation was 81.2 ft (range 79.5 to 84.3 ft) (Appendix 1). Mean spill bay discharges at release times through spill bays 4, 9, and 13 were 5.8, 4.3, and 2.5 KCFS, respectively. The summer release period was 02 July through 22 July and the mean percent spill discharge was 95 KCFS (range 56 to 200 KCFS), mean total project discharge was 235 KCFS (138 to 330 KCFS), mean percent spill of the total project discharge was 40% (range 30 to 77%) and mean tailwater elevation was 80.3 ft (range 77.7 to 83.2 ft) (Appendix 2). Mean spill bay discharges at release times from 02 July through 12 July were 5.9 KCFS at spill bay 4 and 2.9 KCFS at spill bay 13. Discharges at these bays after July 12 were not available from the COE.

Fish Released and Detected

From 01 May to 01 June, we radio-tagged and released 943 yearling Chinook salmon (detailed summaries of fish releases through each spill bay are presented in Appendices 3, 4, and 5). The 943 yearling Chinook salmon were divided among the three release sites; 313 fish were released through bay 4 and 315 fish were released through each of bays 9 and 13.

Throughout the spring release period, the aerial antenna array detected 70% of the yearling Chinook salmon released (Table 1) and the underwater antenna array detected 9% (Table 2). The percent detection was similar among spill bay release groups within each array, ranging from 64 to 76% at the aerial array and 6 to 12% at the underwater array. Analyses were based on the aerial array data only due to the low detection percentages of the underwater array.

Table 1. Number of radio-tagged yearling Chinook salmon released through spill bays 4, 9, and 13 during spring 2002, detected by the aerial antenna array at The Dalles Dam.

	Bay 04		Bay 09		Bay 13		Overall	
Release Date (Time)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Total released	Total detected(%)
01-May-2002 (0200)	20	20(100)	20	20(100)	20	20(100)	60	60(100)
03-May-2002 (0800)	20	2(10)	20	1(5)	18	1(5)	58	4(7)
05-May-2002 (0200)	20	0(0)	19	0(0)	20	0(0)	59	0(0)
07-May-2002 (2200)	20	15(75)	20	10(50)	20	20(100)	60	45(75)
09-May-2002 (0800)	19	6(32)	20	10(50)	20	8(40)	59	24(41)
11-May-2002 (2200)	20	19(95)	20	20(100)	20	20(100)	60	59(98)
13-May-2002 (0900)	20	4(20)	20	3(15)	20	8(40)	60	15(25)
15-May-2002 (2200)	20	11(55)	20	15(75)	21	20(95)	61	46(75)
17-May-2002 (0500)	18	12(67)	18	14(78)	19	18(95)	55	44(80)
19-May-2002 (2200)	18	11(61)	20	20(100)	20	17(85)	58	48(83)
21-May-2002 (0500)	20	19(95)	19	18(95)	19	18(95)	58	55(95)
23-May-2002 (2200)	20	15(75)	20	16(80)	19	15(79)	59	46(78)
25-May-2002 (0500)	20	20(100)	19	17(89)	20	19(95)	59	56(95)
27-May-2002 (2200)	20	15(75)	20	19(95)	20	18(90)	60	52(87)
29-May-2002 (0500)	19	17(89)	20	20(100)	20	20(100)	59	57(97)
01-Jun-2002 (0500)	19	15(79)	20	17(85)	19	18(95)	58	50(86)
Total	313	201 (64)	315	220 (70)	315	240 (76)	943	661 (70)

Low rates of detection on the aerial antenna array prior to 15 May were due to a noise source overwhelming the radio-telemetry system; the noise source was identified as a paging system for Mid-Columbia Medical Center (The Dalles, Oregon) operating at 152.240 MHz. Upon determining the frequency, Grant System Engineering manufactured and installed filters to alleviate the problem. During the period the filters were being built, we scheduled the morning fish releases to occur earlier at 0500 hours, (before increased use of the hospital paging system) to minimize the impact of the paging system. The low rate of detection on the underwater antenna array was due to structural damage sustained during high spill discharge, as indicated by post-season inspection by divers.

Table 2. Number of radio-tagged yearling Chinook salmon released through spill bays 4, 9, and 13 during spring 2002, detected by the underwater antenna array at The Dalles Dam.

	Bay 04		Bay 09		Bay 13		Overall	
Release Date (Time)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Total released	Total detected(%)
01-May-2002 (0200)	20	0(0)	20	1(5)	20	1(5)	60	2(3)
03-May-2002 (0800)	20	7(35)	20	1(5)	18	3(17)	58	11(19)
05-May-2002 (0200)	20	4(20)	19	2(11)	20	2(10)	59	8(14)
07-May-2002 (2200)	20	1(5)	20	0(0)	20	0(0)	60	1(2)
09-May-2002 (0800)	19	1(5)	20	1(5)	20	1(5)	59	3(5)
11-May-2002 (2200)	20	1(5)	20	1(5)	20	1(5)	60	3(5)
13-May-2002 (0900)	20	2(10)	20	3(15)	20	1(5)	60	6(10)
15-May-2002 (2200)	20	1(5)	20	1(5)	21	3(14)	61	5(8)
17-May-2002 (0500)	18	1(6)	18	0(0)	19	4(21)	55	5(9)
19-May-2002 (2200)	18	1(6)	20	2(10)	20	2(10)	58	5(9)
21-May-2002 (0500)	20	2(10)	19	2(11)	19	1(5)	58	5(9)
23-May-2002 (2200)	20	2(10)	20	2(10)	19	1(5)	59	5(8)
25-May-2002 (0500)	20	3(15)	19	0(0)	20	4(20)	59	7(12)
27-May-2002 (2200)	20	5(25)	20	1(5)	20	3(15)	60	9(15)
29-May-2002 (0500)	19	2(11)	20	1(5)	20	0(0)	59	3(5)
01-Jun-2002 (0500)	19	4(21)	20	1(5)	19	1(5)	58	6(10)
Total	313	37(12)	315	19(6)	315	28(9)	943	84(9)

From 02 July to 22 July, we radio-tagged 911 subyearling Chinook salmon and released them into spill bays 4 (N = 470) and 13 (N = 441). On 10 July, fish were released through spill bay 11 instead of spill bay 13, because spill bay 13 was not operating. This release of 23 fish was excluded from all analyses (summaries of fish releases are provided in Appendices 6 and 7). Aerial detections in the summer were much higher than during the spring (95% overall fish detection; Table 3) but the overall underwater array detections were similar during both periods (8% spring and 9% summer; Table 4).

Table 3. Number of radio-tagged subyearling Chinook salmon released through spill bays 4 and 13 during summer 2002, detected by the aerial antenna array at The Dalles Dam.

	Bay 04		Bay 13		Overall	
Release Date (Time)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Total released	Total detected(%)
02-July-2002 (0000)	23	22(96)	23	23(100)	46	45(98)
02-July-2002 (0500)	21	20(95)	21	20(95)	42	40(95)
03-July-2002 (2200)	17	17(100)	16	15(94)	33	32(97)
05-July-2002 (2200)	25	23(92)	24	24(100)	49	47(96)
06-July-2002 (0500)	25	25(100)	24	23(96)	49	48(98)
08-July-2002 (0500)	24	22(92)	25	23(92)	49	45(92)
09-July-2002 (2200)	25	25(100)	25	25(100)	50	50(100)
10-July-2002 (0500)	25	24(96)	0*	.	25	24(96)
11-July-2002 (2200)	22	18(82)	18	18(100)	40	36(90)
12-July-2002 (0500)	25	24(96)	25	24(96)	50	48(96)
13-July-2002 (2200)	18	16(89)	18	18(100)	36	34(94)
14-July-2002 (0500)	23	22(96)	25	25(100)	48	47(98)
15-July-2002 (2200)	25	23(92)	25	25(100)	50	48(96)
16-July-2002 (0500)	25	22(88)	24	24(100)	49	46(94)
17-July-2002 (2200)	25	23(92)	25	25(100)	50	48(96)
18-July-2002 (0500)	25	23(92)	24	24(100)	49	47(96)
19-July-2002 (2200)	24	20(83)	25	24(96)	49	44(90)
20-July-2002 (0500)	22	22(100)	25	24(96)	47	46(98)
21-July-2002 (2200)	26	23(88)	25	23(92)	51	46(90)
22-July-2002 (0500)	25	24(96)	24	24(100)	49	48(98)
Total	470	438(93)	441	431(98)	911	869(95)

*23 fish were released into SB11, not included in analysis

Of the 470 subyearling Chinook salmon released into spill bay 4, 93% (*N* = 437) were detected by the aerial antenna array and 8% (*N* = 38) were detected on the underwater antenna array. Aerial detections of subyearling Chinook salmon released through spill bay 13 were slightly higher, with 430 of 441 (98%) fish being detected. Seven percent (33 of 441) of fish released at spill bay 13 were detected on the underwater antenna array.

Table 4. Number of radio-tagged subyearling Chinook salmon released through spill bays 4 and 13 during summer 2002, detected by the underwater antenna array at The Dalles Dam.

	Bay 04		Bay 13		Overall	
Release Date (Time)	Fish released	Fish detected(%)	Fish released	Fish detected(%)	Total released	Total detected(%)
02-July-2002 (0000)	23	2(9)	23	0(0)	46	2(4)
02-July-2002 (0500)	21	0(0)	21	0(0)	42	0(0)
03-July-2002 (2200)	17	2(17)	16	4(25)	33	6(18)
05-July-2002 (2200)	25	4(16)	24	0(0)	49	4(8)
06-July-2002 (0500)	25	1(4)	24	0(0)	49	1(2)
08-July-2002 (0500)	24	2(8)	25	3(12)	49	5(10)
09-July-2002 (2200)	25	2(8)	25	1(4)	50	3(6)
10-July-2002 (0500)	25	0(0)	0*	.	25	0(0)
11-July-2002 (2200)	22	0(0)	18	3(17)	40	3(8)
12-July-2002 (0500)	25	2(8)	25	2(8)	50	4(8)
13-July-2002 (2200)	18	1(6)	18	1(6)	36	2(6)
14-July-2002 (0500)	23	2(9)	25	3(12)	48	5(10)
15-July-2002 (2200)	25	5(20)	25	4(16)	50	9(18)
16-July-2002 (0500)	25	3(12)	24	0(0)	49	3(6)
17-July-2002 (2200)	25	2(8)	25	1(4)	50	3(6)
18-July-2002 (0500)	25	4(16)	24	1(4)	49	5(10)
19-July-2002 (2200)	24	1(4)	25	2(8)	49	3(6)
20-July-2002 (0500)	22	0(0)	25	2(8)	47	2(4)
21-July-2002 (2200)	26	0(0)	25	0(0)	51	0(0)
22-July-2002 (0500)	25	5(20)	24	6(25)	49	11(22)
Total	470	38(8)	441	33(7)	911	71(8)

*23 fish were released into SB11, not included in analysis

Lateral Distribution of Fish

Fish from each release site exhibited some northward lateral movement in the stilling basin, but lateral movement was most evident in the fish released through spill bay 13. Eighty-six percent of the yearling Chinook salmon released through bay 13 were last detected to the north of the release site, with 51% last detected downstream of bays 11 to 8 and 35% last detected downstream of bays 7 to 1 (Figure 5). Based on last detection location, 52% of yearling Chinook salmon released through spill bay 9 moved

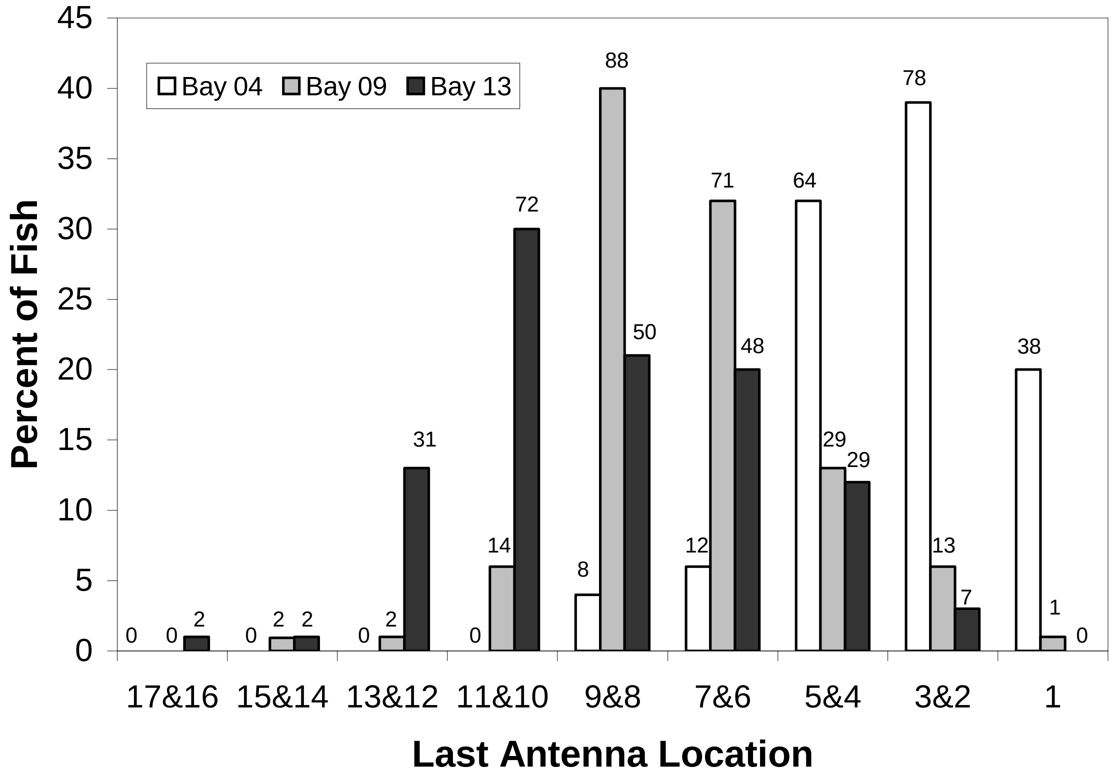

Figure 5. Distribution of detections based on the aerial antenna at which yearling Chinook salmon were last detected after release through spill bay 4 (N = 201 detections), spill bay 9 (N = 220 detections), and spill bay 13 (N = 240 detections). Numbers above bars indicate the individual detections.

northward at least one spill bay after release, and 20% of the fish were detected between bays 5 and 1. Fifty-nine percent of the yearling Chinook salmon released through bay 4 were last detected north of the release site, and 20% of those were detected downstream of bay 1.

The lateral movement patterns of subyearling Chinook salmon were similar to those of yearling Chinook salmon (Figure 6). Eighty-four percent of subyearling Chinook salmon released from spill bay 13 were last detected downstream of spill bays to the north of the release site; 59% of the fish were last detected between bays 11 and 8 and 26% were last detected between bays 7 and 1. Forty-seven percent of subyearling Chinook salmon released through bay 4 moved toward the north, and 22% were last detected in the area of spill bay 1.

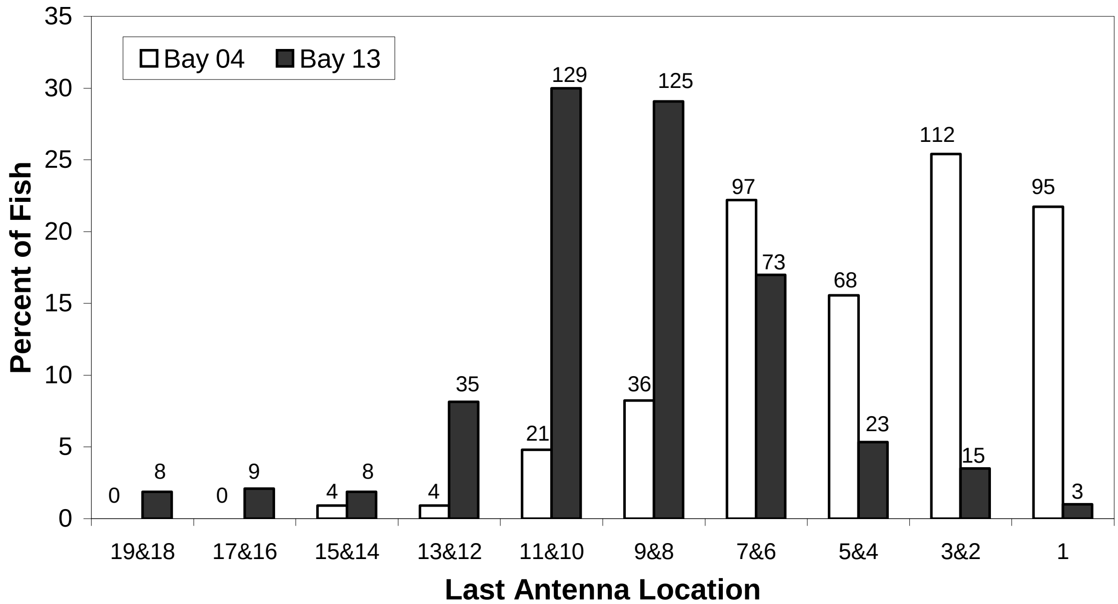

Figure 6. Distribution of detections based on the aerial antenna at which subyearling Chinook salmon were last detected after release through spill bay 4 (N = 437 detections) and spill bay 13 (N = 430 detections). Numbers above bars indicate the individual detections.

In examining the detection histories of individual fish, it was noted that the last aerial detection was not always the most northern detection. For example, a fish may move laterally northward in the area between the spillway and baffle blocks and then move laterally toward the south as it crosses the end sill. So, an analysis was conducted using the most northern antenna detection as a measure of lateral distance traveled in the stilling basin. The trends were similar to the analysis based on the antenna of last detection, but it is apparent that some fish are moving further to the north than the area of last detection (Figures 7 and 8). Based on the northernmost detection, 87% of the yearling Chinook salmon released from bay 13, 64% released from bay 9, and 73% released from bay 4 exhibited lateral movement toward the north, compared to 86, 52 and 59% from the previous analysis. Similarly, subyearling Chinook salmon detections indicated more northward movement when using the most northern antenna detection, with 96 and 85% moving north laterally from bays 13 and 4, respectively, compared to 84 and 47% when based on the antenna of last detection.

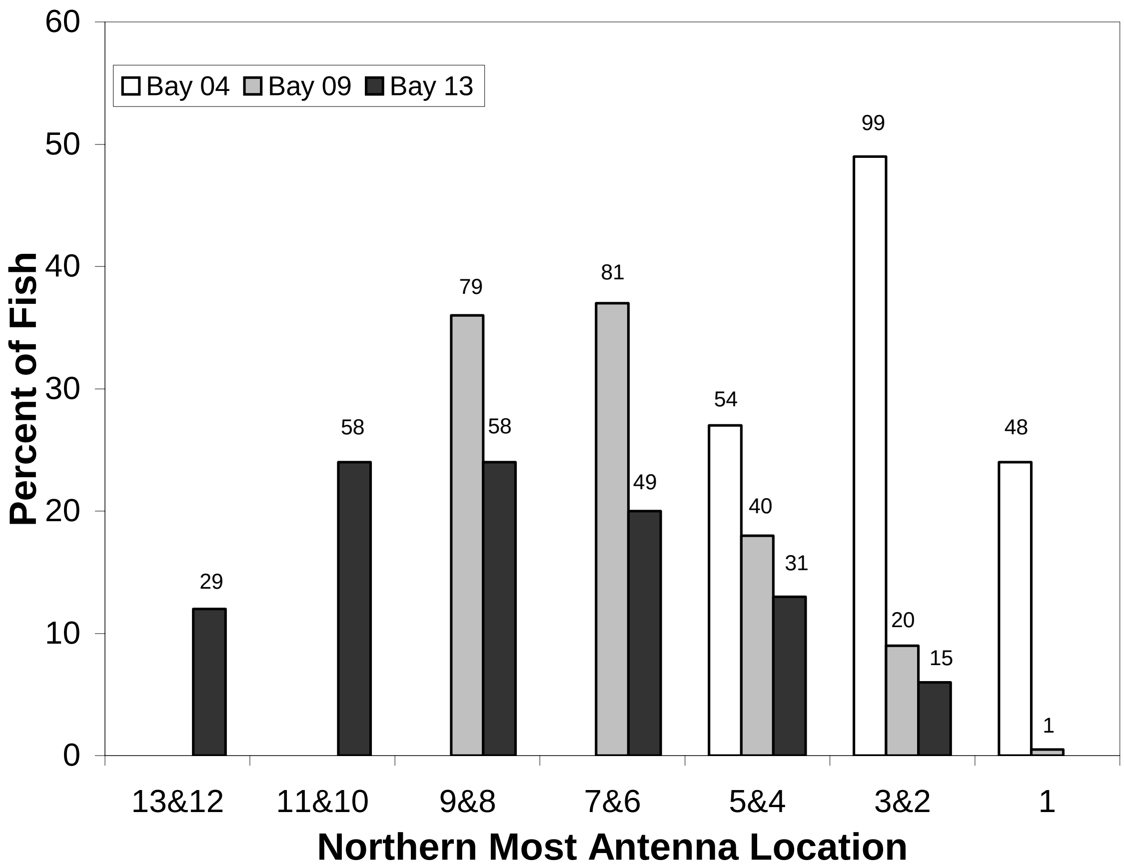

Figure 7. Distribution of detections based on the northernmost aerial antenna at which yearling Chinook salmon were detected after release through spill bay 4 (*N* = 201 detections), spill bay 9 (*N* = 220 detections), and spill bay 13 (*N* = 240 detections). The northernmost antennas are to the right of the figure. Numbers above bars indicate the individual detections.

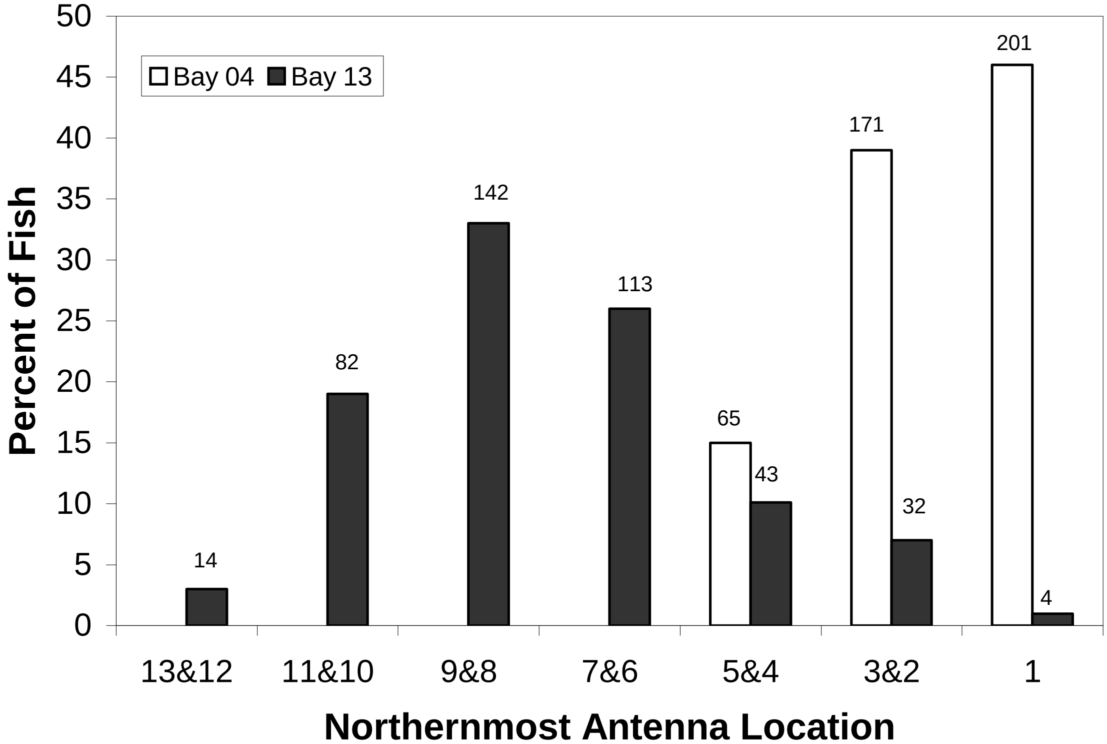

Figure 8. Distribution of detections based on the northernmost aerial antenna at which subyearling Chinook salmon were detected at after release through spill bay 4 (N = 437 detections) and spill bay 13 (N = 430 detections). North is to the right in the figure. Numbers above bars indicate the individual detections.

Residence Time of Fish in the Stilling Basin

The median residence times of fish released through spill bay 13 were longer than residence times of fish released from bays 9 and 4. Yearling Chinook salmon released from bay 13 had a median residence time of 1.6 min, ranging from 0.6 to 64.2 min (Table 5 and Figure 9). The median residence times of yearling Chinook salmon released from bays 9 and 4 were both 1.0 min (range 0.1 to 65.2 min) and (range 0.1 to 32.9 min), respectively. The 95th percentile residence times of fish from bays 13, 9 and 4 were 8.0, 2.1 and 3.5 min, respectively. Summaries of residence times of yearling Chinook salmon are in Appendices 8 and 9.

Table 5. Median residence times of yearling Chinook salmon released through spill bays 4, 9, and 13 at The Dalles Dam, spring 2002. N=sample size. min=minutes.

	Release site								
	Bay 04			Bay 09			Bay 13		
Release date	Median residence time (min)	Range	N	Median residence time (min)	Range	N	Median residence time (min)	Range	N
01-May-2002	2.2	1.6-14.5	20	1.7	0.9-6.1	20	4.7	2.4-10.1	20
03-May-2002	0.9	0.6-2.1	8	0.3	0.1-0.5	2	1.5	0.7-13.0	4
05-May-2002	0.9	0.6-2.3	4	1.2	0.9-1.4	2	1.0	0.9-1.0	2
07-May-2002	1.0	0.2-2.8	15	1.1	0.7-1.6	10	1.8	0.9-23.9	20
09-May-2002	1.2	0.5-18.7	7	1.2	0.4-13.5	11	1.4	0.7-21.3	8
11-May-2002	1.3	0.6-20.7	19	1.2	0.1-12.2	20	1.7	1.0-13.4	20
13-May-2002	1.1	0.2-3.5	6	1.2	0.2-2.0	4	1.1	0.6-4.4	9
15-May-2002	1.0	0.6-1.5	11	0.6	0.2-65.2	15	2.2	0.7-64.2	20
17-May-2002	1.3	0.9-32.9	12	0.8	0.6-4.9	14	2.0	0.7-14.4	18
19-May-2002	1.0	0.8-1.2	11	1.1	0.4-2.9	20	1.7	0.9-7.0	17
21-May-2002	1.4	0.5-5.0	19	1.2	0.6-2.0	18	1.3	0.6-8.1	18
23-May-2002	0.6	0.2-1.1	15	0.8	0.3-1.2	16	1.5	0.7-8.0	15
25-May-2002	0.9	0.1-3.6	20	0.8	0.6-1.1	17	1.4	0.8-2.1	19
27-May-2002	0.9	0.1-3.3	15	1.1	0.4-2.0	19	1.5	0.8-2.5	18
29-May-2002	0.8	0.3-1.3	17	0.8	0.4-2.2	20	1.3	0.6-2.0	20
01-Jun-2002	1.0	0.4-4.3	15	0.9	0.1-1.8	17	1.4	1.0-3.0	18
Pooled	1.0	0.1-32.9	214	1.0	0.1-65.2	225	1.6	0.6-64.2	246

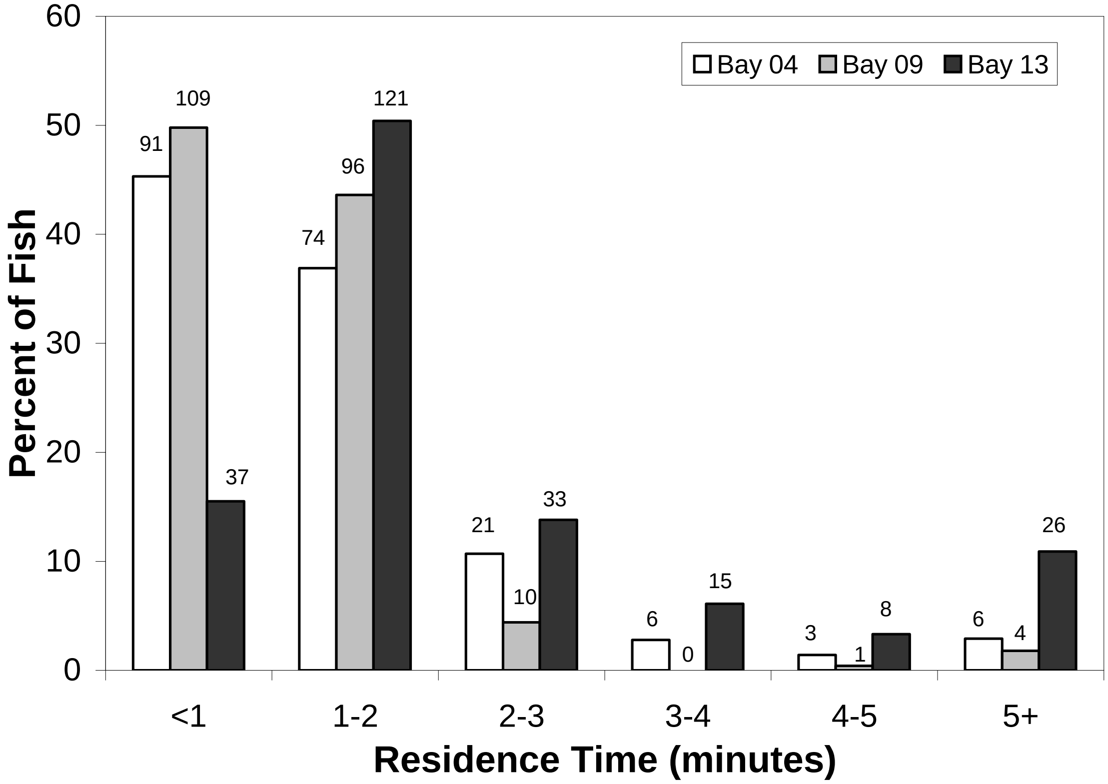

Figure 9. Stilling basin residence times of yearling Chinook salmon released from spill bays 4, 9, and 13. Residence times were estimated using aerial antenna detections. Numbers above bars indicate the individual detections.

Results of the 2-way ANOVAs showed no significant interactions between release site and release day (F = 1.00, df = 14, and P = 0.4490). The residence times from the three release sites were significantly different for the day releases, F = 12.73, df = 2, P < 0.0001. Results of the multiple range test indicated that the residence times from bay 13 were significantly different than those of both SB04 and SB09, but the residence times of bays 4 and 9 were not significantly different.

Results of the 2-way ANOVAs indicated a significant interaction of release site and release day in the mean residence times of the night releases ($F = 1.72$, df = 14, and $P = 0.0493$). Plotting the data revealed this was due to data from the May 01 release date, so the release data for 01 May was removed from the model and analyzed separately using a one-way ANOVA. The results of the analysis based on the remaining night releases ($N = 7$) indicated no significant interaction between release site and release day ($F = 1.31$, df = 12, and $P = 0.2117$), so a reduced model (no interaction term) was used for final analysis, and the mean residence times were significantly different between release sites ($F = 10.84$, df = 2, $P < 0.0001$). The REGW multiple range tests for night releases indicated that the residence time for bay 13 was significantly different than both bays 4 and 9, but residence times for bays 4 and 9 were not significantly different.

The median residence time of subyearling Chinook salmon released through spill bay 13 was 1.8 min (range 0.1 to 51.7 min), whereas those released through bay 4 had a median residence time of 1.4 min (range 0.1 to 31.6 min). Ninety-five percent of the detected subyearling Chinook salmon released from bay 13 exited the aerial detection array in 13.6 min, while the 95th percentile residence time for detected fish from bay 4 was 6.6 min. Approximately 25% of the detected subyearling Chinook salmon released from bay 4 exited the detection array in less than one minute, while fewer than 11% of the subyearling Chinook salmon released from bay 13 exited in that time (Table 6 and Figure 10). Residence time summaries of subyearling Chinook salmon are in Appendices 10 and 11.

The results of the 2-way ANOVAs conducted on both day and night release data were similar to those in the spring data. We found no significant interactions between release site and release day (F = 0.76, df = 8, and P = 0.6398), and that mean residence times at the three release sites were significantly different for the day releases (F = 17.14, df = 1, P < 0.0001). Similarly, no significant interactions between release site and release day were evident for the night releases (F = 0.62, df = 9, and P = 0.7813), and the mean residence times at the three release sites were significantly different (F = 18.20, df = 1, P < 0.0001).

Table 6. Median residence time of subyearling Chinook salmon released through spill bays 4 and 13 at The Dalles Dam, summer 2002. N=sample size. min=minutes.

	Release site					
	Bay 04			Bay 13		
Release date	Median residence Time (min)	Range	N	Median residence time (min)	Range	N
02-July-2002	1.4	0.8–14.7	22	2.0	1.0-15.7	23
02-July-2002	1.1	0.7-7.7	20	1.4	0.9-6.8	20
03-July-2002	1.6	1.0-22.3	17	2.5	1.4-26.3	15
05-July-2002	1.5	0.8-16.5	23	1.9	0.8-3.5	24
06-July-2002	1.6	1.1-7.6	25	2.6	1.2-19.6	23
08-July-2002	0.8	0.1-19.0	22	1.6	0.3-14.0	23
09-July-2002	1.1	0.5-18.9	25	1.6	0.6-5.7	25
10-July-2002	1.4	0.9-2.3	24	.	.	00*
11-July-2002	1.0	0.7-1.7	18	1.4	0.5-4.4	18
12-July-2002	1.7	0.7-20.8	24	2.8	0.1-22.4	24
13-July-2002	0.9	0.1-14.1	16	1.3	0.8-7.6	18
14-July-2002	1.4	0.1-31.6	22	1.8	0.7-21.4	25
15-July-2002	1.4	0.7-23.4	23	2.0	1.2-51.7	25
16-July-2002	1.6	0.1-4.5	22	2.4	1.1-17.0	24
17-July-2002	1.3	0.7-5.0	23	1.3	0.7-3.7	25
18-July-2002	1.7	0.1-6.2	23	1.8	1.0-20.5	24
19-July-2002	1.3	0.1-2.5	20	1.5	0.8-23.8	24
20-July-2002	1.6	0.9-12.4	22	1.6	0.6-36.5	24
21-July-2002	0.8	0.4-6.4	23	1.4	0.8-4.0	23
22-July-2002	1.7	0.7-15.7	24	2.1	0.2-20.8	24
Pooled	1.4	0.1-31.6	438	1.8	0.1-51.7	431

*23 fish were released into SB11, not included in analysis

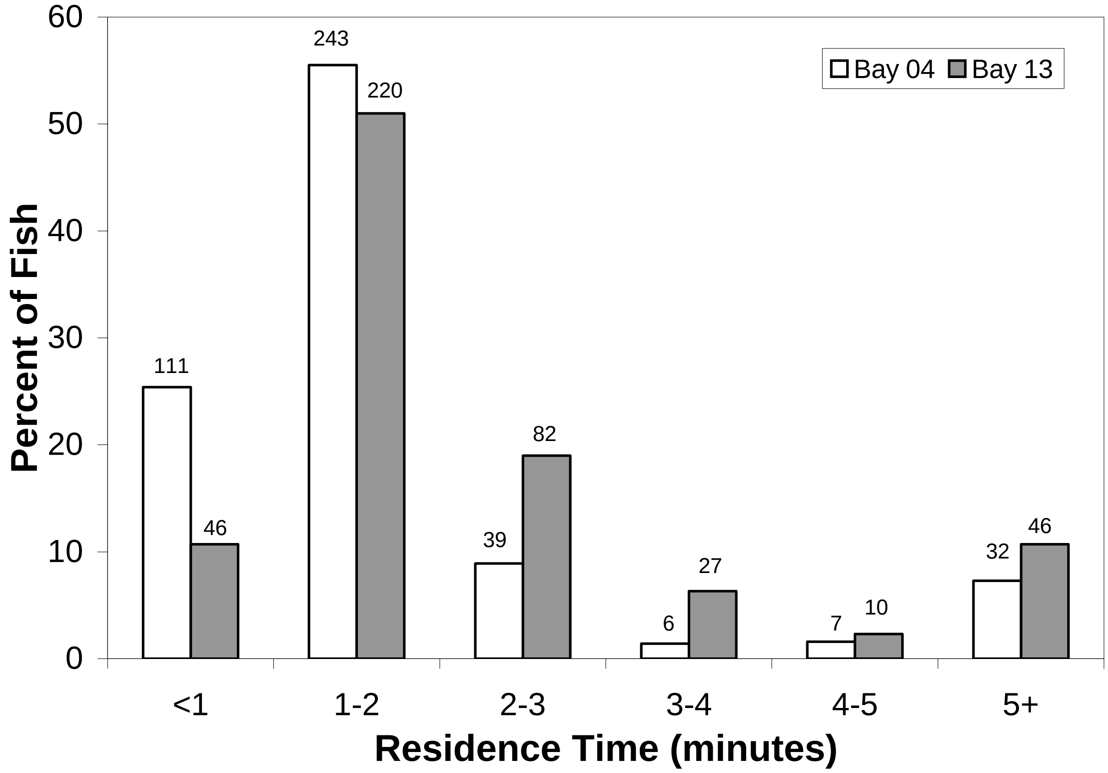

Figure 10. Stilling basin residence times of subyearling Chinook salmon released from spill bays 4 and 13. Residence times were estimated using aerial antenna detections. Numbers above bars indicate the individual detections.

The median stilling basin residence times of fish increased with the lateral distance traveled from the release site (Figure 11). For example, yearling Chinook salmon released through bay 13 that did not move northward laterally had a median residence time of 0.9 min (range 0.6 to 21.3 min) and the median residence time of fish that moved northward to bays 3 and 2 was 4.1 min (range 1.8 to 64.2 min). This trend is also evident in median residence times of fish released through spill bay 9 and to a lesser extent in fish released through spill bay 4.

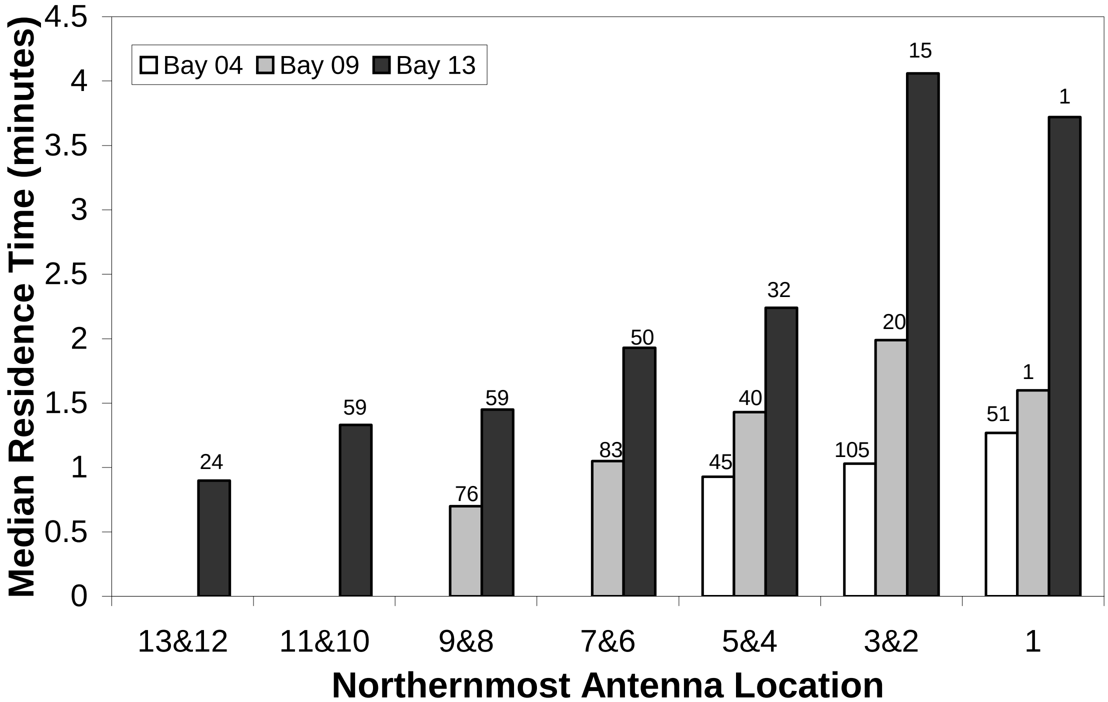

Figure 11. Median residence times of yearling Chinook salmon released through spill bays 4, 9, and 13 by the location of the northernmost antenna they were detected at. North is to the right in the figure. Numbers above bars indicate sample size.

The median residence times of subyearling Chinook salmon also increased with the lateral distance traveled from their release site (Figure 12). Subyearling Chinook salmon released through bay 13 that did not move northward laterally had a median residence time of 1.4 min (range 0.8 to 19.6 min), whereas the median residence time of fish that moved north laterally and were detected downstream of bays 3 and 2 was 2.9 min (range 1.4 to 51.7 min). This same trend is evident, although to a lesser degree, in median residence times of subyearling Chinook salmon released through spill bay 4 with a median residence time of 1.0 min (range 0.7 to 14.1 min) for fish that did not move north laterally and 1.4 min (range 0.8 to 23.4 min) for fish detected downstream of bays 3 through 1.

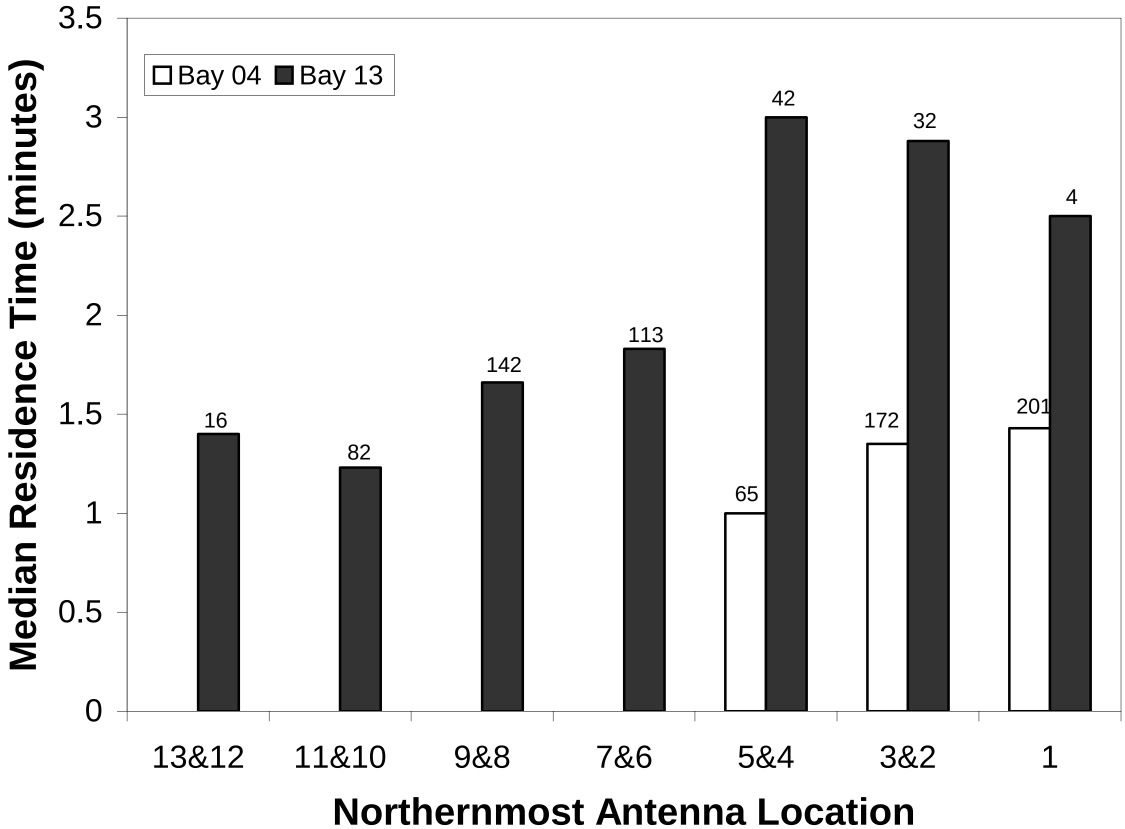

Figure 12. Median residence times of subyearling Chinook salmon released through spill bays 4 and 13 by location of the northernmost antenna they were detected at. North is to the right in the figure. Numbers above bars indicate sample size.

Lateral Distribution of Drogues

Drogues released through spill bay 13 showed the most lateral movement. Between 5 May and 7 August 2002, we released 83 drogues at the TDA spillway: 36 at bay 4, 14 at bay 9, and 33 at bay 13 (Table 7). Overall, 75% of the drogues moved laterally at least one bay and 23% were transported four or more bays. Representative drogue paths for each release location are shown in Figure 13 and paths of all individual drogues are presented in Appendix 12. Every drogue released from spill bay 13 (N = 33) showed some lateral movement (at least one bay), whereas less frequent lateral movement was shown by drogues released at bay 9 (71%) and bay 4 (53%). Approximately half of the drogues released at bays 4 (53%) and 9 (57%) remained within one bay of the release location (Figure 14). At bay 13, however, only 22% of drogues remained within one bay, and 3% of the drogues moved laterally to spill bay 1 (Figure 14).

Table 7. Deployment dates, location, sample size (N) and dam operations for drogues released at The Dalles Dam spillway, 2002. Discharge data from http://www.nwd-wc.usace.army.mil/TMT.

Deployment Date	Deployment Location	Mean Total Discharge (KCFS)	Mean Spill Discharge (KCFS)	N
5-May-2002	SPILLBAY 04	245.9	95.2	6
12-May-2002	SPILLBAY 09	142.8	57.0	4
17-May-2002	SPILLBAY 13	222.0	84.9	5
22-May-2002	SPILLBAY 09	263.2	84.2	5
25-May-2002	SPILLBAY 04	251.7	98.9	5
26-May-2002	SPILLBAY 09	259.6	99.2	5
31-May-2002	SPILLBAY 13	324.3	73.8	5
3-Jun-2002	SPILLBAY 13	311.5	73.6	5
4-Jun-2002	SPILLBAY 04	385.0	116.6	5
6-Jul-2002	SPILLBAY 13	263.4	102.0	5
7-Jul-2002	SPILLBAY 04	214.5	84.0	5
9-Jul-2002	SPILLBAY 13	188.9	71.8	5
11-Jul-2002	SPILLBAY 04	164.1	62.0	5
15-Jul-2002	SPILLBAY 13	230.4	115.0	5
17-Jul-2002	SPILLBAY 04	230.5	88.0	5
23-Jul-2002	SPILLBAY 04	183.4	72.6	5
7-Aug-2002	SPILLBAY 13	158.6	63.2	3
Total				83

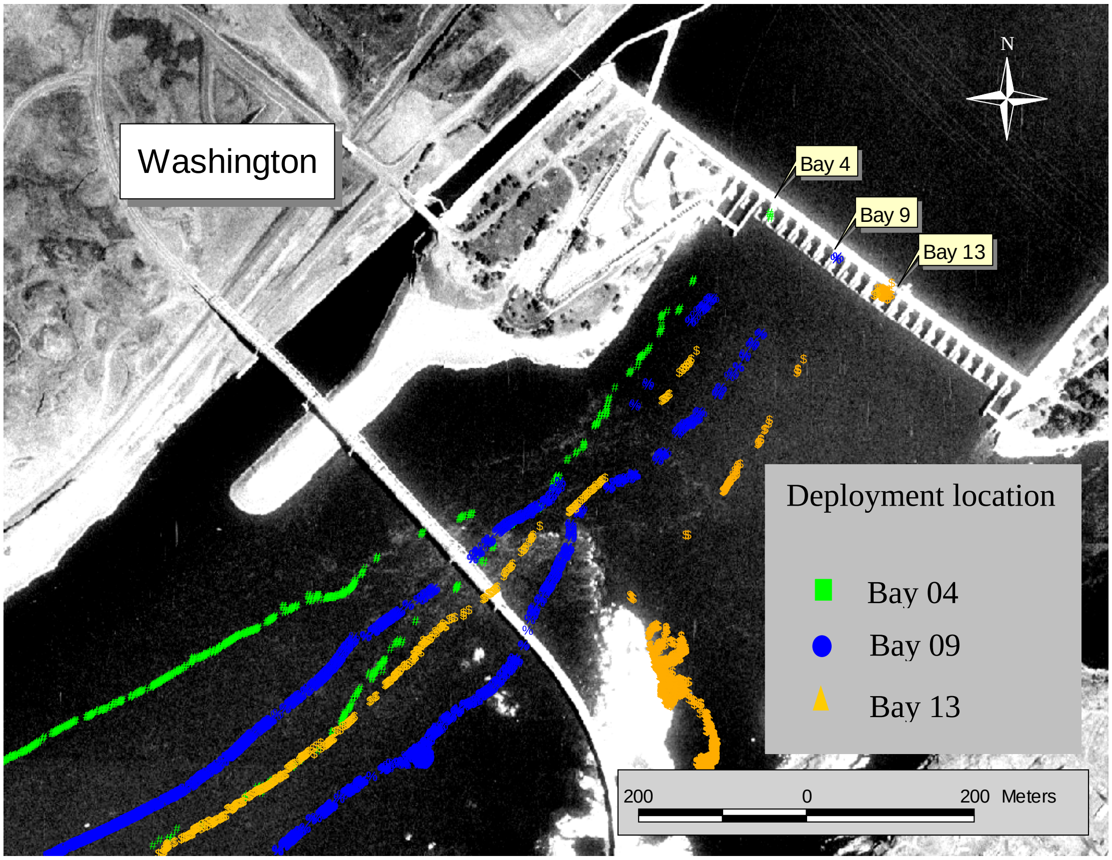

Figure 13. Representative drogue movement paths following spillway releases at The Dalles Dam from 5 May to 7 August 2002. Drogues were released through spill bay 4, spill bay 9 and spill bay 13. Two representative drogue paths were chosen for each of the three release locations (*N* = 6). Background photo does not represent study conditions.

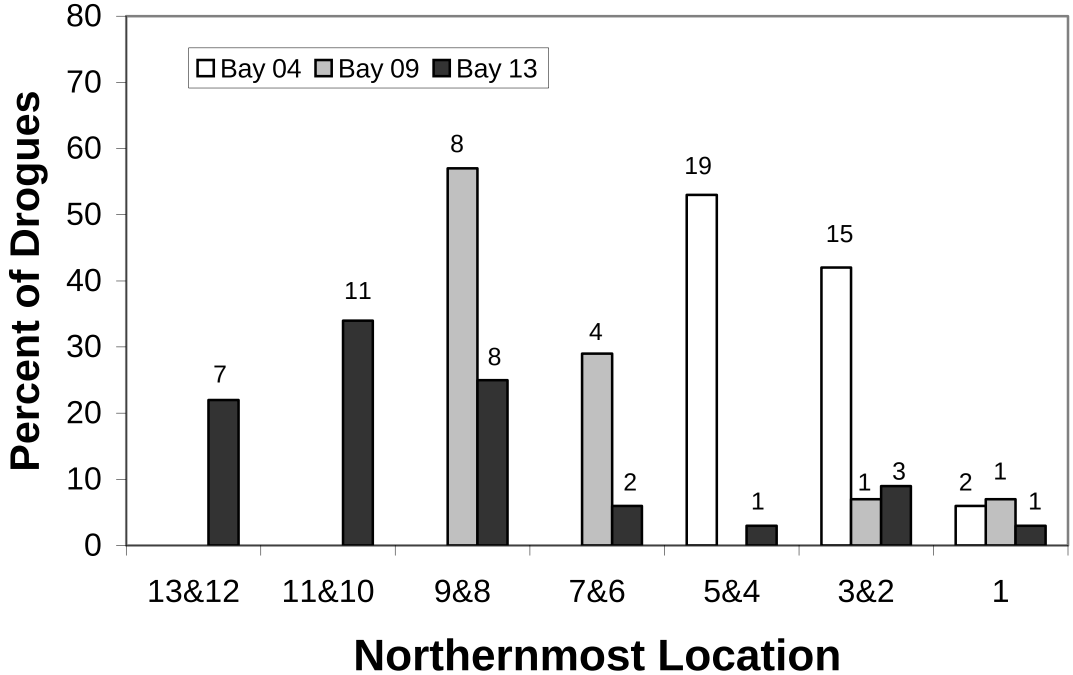

Figure 14. Northernmost location of drogues released at spill bays 4, 9, and 13 at The Dalles Dam spillway, 2002. North is to the right in the figure. Sample sizes (number of drogues) are shown above each bar.

Drogue Travel Time

Drogues released from bays 4, 9, and 13 had similar median travel times to the basin islands, however there was a wide range of travel times to the bridge (Figure 15). Drogues released at bay 13 had longer travel times (range 1.8 to 19.9 min) to the Highway 197 bridge than drogues released at bays 4 (range 2.0 to 4.3 min) or 9 (range 2.4 to 6.1 min). The range of travel times to the basin islands followed the same trend with the largest range of travel times from drogues released at bay 13 (range 13.3 to 55.4 min) compared to bay 4 (range 5.5 to 32.0 min) and bay 9 (range 13.4 to 31.4 min).

Drogues that traveled laterally across the spillway had longer travel times to the bridge than those that traveled directly out of the tailrace. The most notable effect was at spill bay 4. Drogues released at bay 4 which moved laterally at least one bay had a median travel time of 3.5 min (N = 18, range 2.4 to 4.3 min). Drogues that showed no lateral transport had shorter travel times (median =2.9 min, N = 17, range 2.0 to 4.0 min). Drogues released at spill bay 9 had similar travel times regardless of travel route. The median travel times for drogues released at bay 9 were 2.9 min (N = 8, range 2.4 to 6.1 min) for laterally transported drogues, and 2.8 min (N = 4, range 2.7 to 3.2 min) for drogues with a more direct travel route. Though their travel times were similar, the between-drogue variability was greater for drogues that were laterally transported than those with direct routes. All drogues released at spill bay 13 moved laterally. Due to a large variation in spill discharge, total project discharge, and tailwater elevation between release dates, no statistical comparisons of data from drogues were made.

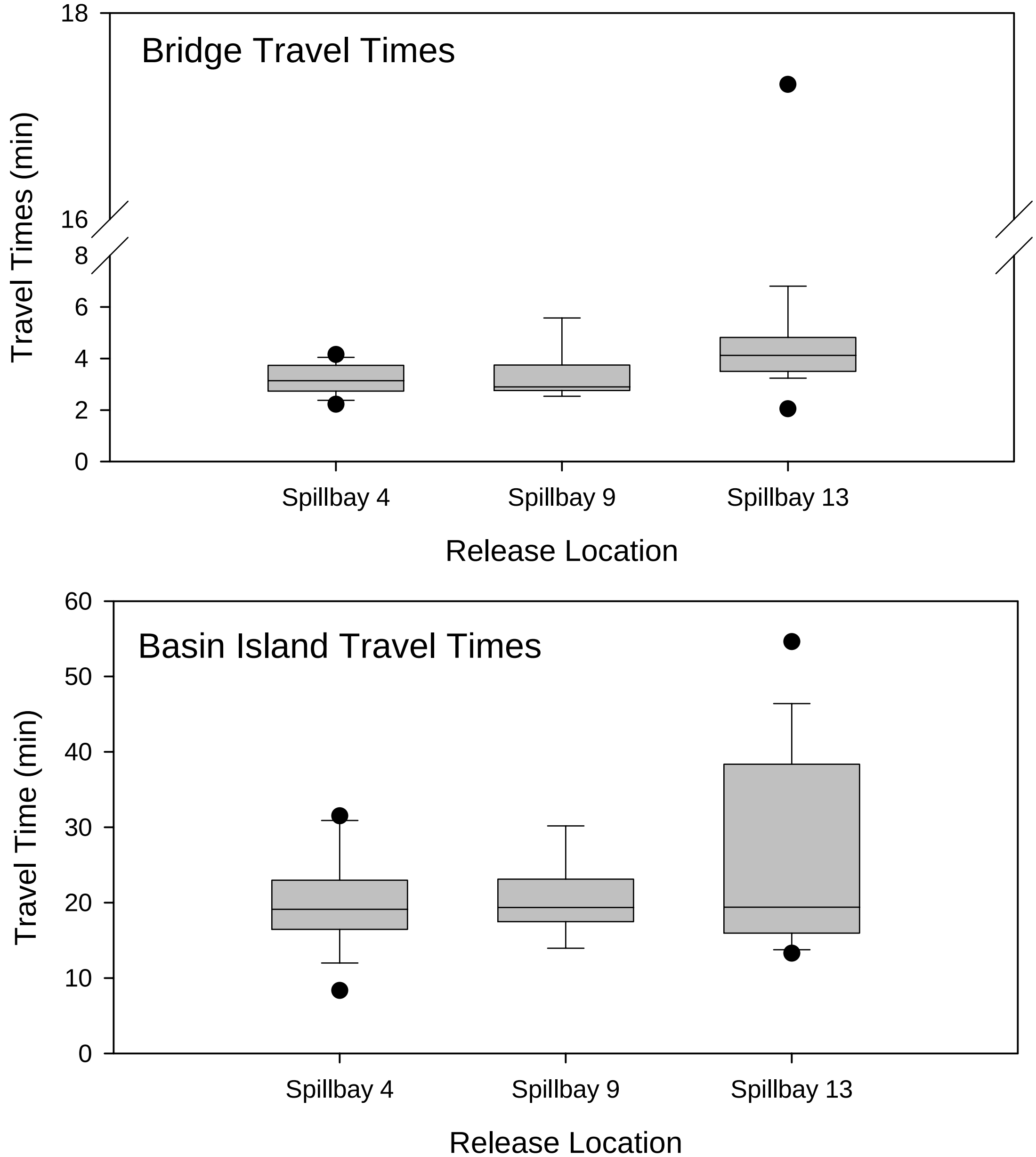

Figure 15. Median travel times of drogues released at spill bays 4, 9 and 13 at The Dalles Dam, 2002. Travel times were calculated from the time of release to the time of arrival at the Highway 197 Bridge (0.6 km downstream) and the Basin Island (1.6 km downstream). The lower boundary of the box indicates the 25^{th} percentile, the line within the box marks the median value, and the upper boundary of the box indicates the 75^{th} percentile. Whiskers below and above the boxes indicates the 10^{th} and 90^{th} percentile. Circles indicate 5^{th} and 95^{th} percentiles.

Discussion

Radio-tagged juvenile Chinook salmon released through three spill bays were commonly detected north of the release sites, indicating that fish are either actively swimming with, or becoming entrained in, a lateral transport flow pattern in the stilling basin. Eighty-six percent of yearling Chinook salmon and 84% of subyearling Chinook salmon released through spill bay 13, at the southern edge of the spill pattern, were later detected downstream of bays to the north of the release site. Although most of the lateral movement to the north (51% for yearling and 59% for subyearling Chinook salmon) was between the release site and spill bay 7, 35% of yearling Chinook salmon and 26% of the subyearling Chinook salmon were detected in the area between spill bays 7 and 1, a distance greater than 5 spill bays. Northward lateral movement was also evident in fish released from spill bays 9 and 4. Fifty-two percent of yearling Chinook salmon released through spill bay 9 were detected downstream of spill bays 7 through 1. Fish released through the northern most release site (bay 4) also displayed some northward lateral movement, with 59% of yearling Chinook salmon and 47% of subyearling Chinook salmon last detected north of the release site, although the distance traveled north was limited by the proximity to the Washington shore.

Results of this study indicate a greater prevalence of northward lateral movement than in 2001. Beeman et al. (2003) reported northward lateral movement of 42% of yearling Chinook salmon released from bays 9 and 11 (pooled), whereas we estimated that in 2002, 52% of yearling Chinook salmon released from bay 9 moved north laterally in the stilling basin. Additionally, Beeman et al. (2003) reported 26% of yearling

Chinook salmon released from bay 4 (in 2001) moved laterally northward, compared to 59% estimated in this report. These differences may be attributed to increased spill discharge resulting in a probable increase in velocity of northward lateral movement of water in the stilling basin. River discharge in 2001 was extremely low (45% of the 10 year average), which resulted in low spillway discharges, fewer spill bays open to discharge, and a southern edge of spill commonly located between bay 9 and 13. In 2002, river discharge was greater (81% of the 10 year average) and the southern edge of spill during fish releases was commonly at spill bay 14 or 15. The greater river flow allowed us to release fish through spill bay 13, an option that was unavailable in 2001.

In moving our southern most release site to bay 13, we estimated, based on location of last detection, that the portion of yearling Chinook salmon that were moving north laterally in the stilling basin increased from 42% in 2001 (bays 9 and 11 pooled) to 86% in 2002. We also expanded the lateral movement analysis to include the northernmost aerial antenna detection, and found that fish may move further to the north than the area of last detection. It appears that lateral movement northward in the area between the spillway and baffle blocks can be followed by movement to the south. When using the northern most aerial antenna detection to quantify lateral movement, the portion of yearling Chinook salmon that moved north laterally increased 1, 12, and 19% for releases from bays 13, 9, and 4, respectively, and lateral movement of subyearling Chinook salmon increased by 12% from bay 13 and 38% from bay 4.

Fish that moved north laterally in the stilling basin had longer residence times than fish that exited directly from the stilling basin. Residence times increased with the lateral distance traveled from the release site. The difference in median residence times for yearling Chinook salmon released from bay 13 that moved north laterally to the area downstream of bays 3 and 2, and those fish that exited directly through the stilling basin was 3.2 min. For the subyearling Chinook salmon released from bay 13, the difference between median residence times of fish detected downstream of bays 3 and 2 compared to the fish with direct egress was 1.4 min.

Several studies were conducted in 2002 to estimate the survival of fish passing through different spill bays, as well as characterize spillway conditions encountered by passing fish. Counihan et al. (In Review) reported average survival estimates of radio-tagged yearling Chinook salmon released for this study as 98, 95, and 92%, for fish released through spill bays 4, 9, and 13, respectively. Similarly, Normandeau Associates (2003) estimated the survival rates of balloon-tagged juvenile Chinook salmon released through bays 4, 9, and 13 were 98.4, 98.9, and 95.9%. The study of Counihan et al. (In Review) accounted for both direct and indirect mortality from spillway passage to the bridge downstream from the dam. Normandeau Associates (2003) studied direct mortality of spillway passage. In a concurrent study with Normandeau Associates, Pacific Northwest National Laboratory (PNNL) used sensor fish to characterize stilling basin conditions encountered by fish passing through several spill bays, and suggested that fish passing through bays 13 and 11 are subjected to more severe hydraulic conditions during extended residence times. (Normandeau Associates 2003). As part of our study, drogues were released through bays 4, 9, and 13 to characterize the lateral flow patterns encountered while passing through the stilling basin. Most lateral transport was from bay 13 releases, but it was present at bays 9 and 4 as well, thus verifying the lateral flow patterns that our study fish encountered during passage.

Data from radio-tagged fish volitionally passing the spillway indicate that these northward lateral movements are affecting a large proportion of fish passing via the spillway. Passage of radio-tagged fish from concurrent studies at John Day Dam indicates that 59% of yearling Chinook salmon and 56% of subyearling Chinook salmon passed TDA via the spillway (Hausmann et al. 2004). Figure 16 shows the spillway passage routes of the yearling Chinook salmon with regard to water spilled using the juvenile spill pattern. Forty-eight percent of the yearling Chinook salmon (575 of 1,190) passed the spillway between spill bay 9 and the southern edge of spill.

The construction of the training wall in the spillway at The Dalles Dam during the winter of 2003/2004 will change the lateral transport patterns. We recommend these changes be evaluated with regard to fish passage, including lateral movement, residence time, and survival of passing juvenile salmonids.

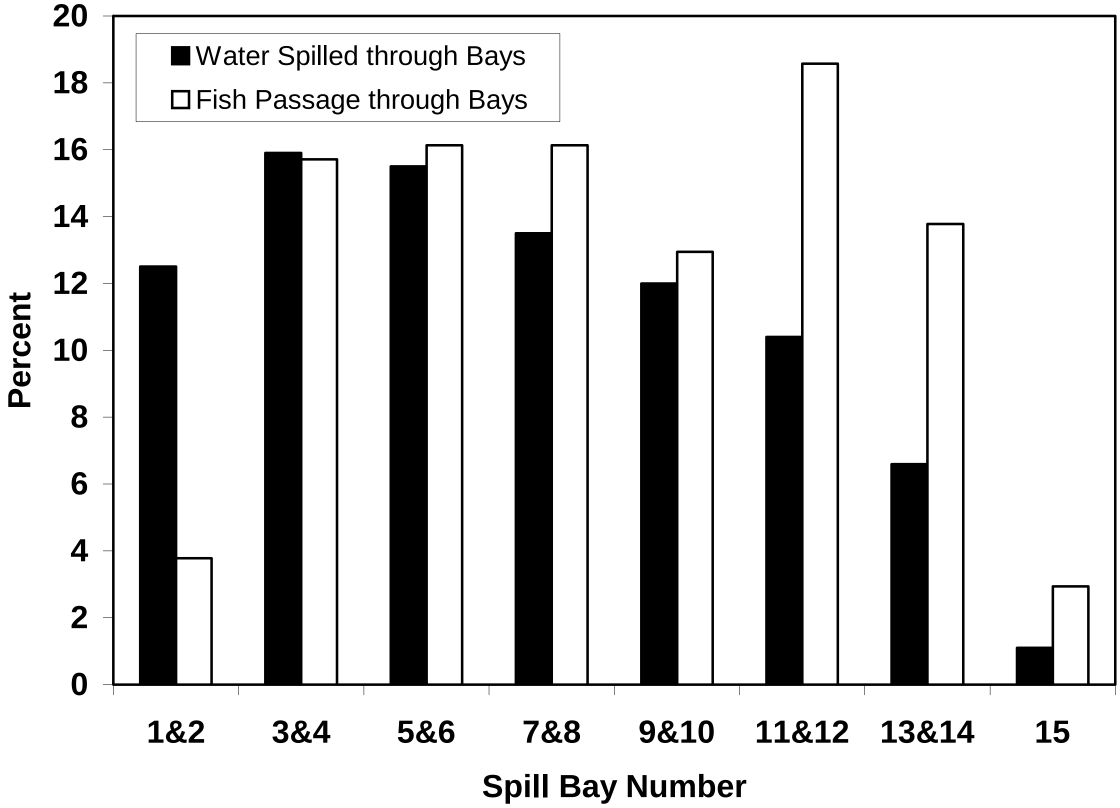

Figure 16. Percent of water spilled through paired spill bays and the percent of volitionally passing radio-tagged yearling Chinook salmon (N=1190) detected passing the paired bays. Fish were released at or near John Day Dam. Data were collected from May 01 through June 01, 2002 during an average project discharge of 235 KCFS and an average spill of 36.7%. Spill bays greater than number 15 were not in operation during this period.

Acknowledgements

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Appendix 1. Spill discharge, total discharge, percent spill, bay 4, 9, and 13 discharge, and spill bays open during the hour of release at The Dalles Dam, Spring 2002. Q = discharge in thousands of cubic feet per second. Tailwater elevation measured in feet.

Release date	Hour	Spill Q	Total Q	Percent spill	Bay 04 Q	Bay 09 Q	Bay 13 Q	Bays open	Tailwater elevation
01-May-2002	0200	50.0	133.8	37.4	5	4	2	1 to 14	79.5
03-May-2002	1000	95.8	274.5	34.9	6	4	3	1 to 15	81.8
05-May-2002	0200	95.2	241.2	39.5	6	4	3	1 to 15	81.3
07-May-2002	2200	105.8	263.5	40.2	6	5	3	1 to 15	81.1
09-May-2002	0800	84.4	227.9	37.0	5	4	2	1 to 14	80.6
11-May-2002	2200	88.9	230.8	38.5	6	4	2	1 to 15	80.9
13-May-2002	0900	86.5	222.9	38.8	6	5	3	1 to 15	79.9
15-May-2002	2200	90.8	219.0	41.5	5	4	2	1 to 14	80.6
17-May-2002	0500	79.2	209.5	37.8	5	4	2	1 to 14	80.0
19-May-2002	2200	82.4	210.5	39.1	5	3	2	1 to 14	80.9
21-May-2002	0500	83.5	242.3	34.5	7	5	3	1 to 15	81.3
23-May-2002	2200	107.2	272.6	39.3	7	5	3	1 to 15	81.3
25-May-2002	0500	99.0	256.0	38.7	7	5	3	1 to 15	81.2
27-May-2002	2200	89.5	278.2	32.2	6	4	2	1 to 15	81.8
29-May-2002	0500	85.0	308.5	27.6	6	4	3	1 to 14	83.4
01-Jun-2002	0500	74.8	313.9	23.8	5	4	2	1 to 14	84.3
Mean		87.4	244.1	36.3	5.8	4.3	2.5		81.2

Appendix 2. Spill discharge, total discharge, percent spill, bay 4 and 13 discharge, and spill bays open during the hour of release at The Dalles Dam, Summer 2002. Q = discharge in thousands of cubic feet per second. . = not available. Tailwater elevation measured in feet.

Release date	Hour	Spill Q	Total Q	Percent spill	Bay 04 Q	Bay 13 Q	Bays open	Tailwater elevation
02-July-2002	0000	100	261.7	38.2	6	3	1 to 15	81.4
02-July-2002	0500	200	258.3	77.4	10	7	1 to 18	80.4
03-July-2002	2200	100	329.8	30.3	6	3	1 to 15	83.2
05-July-2002	2200	104	254.6	40.8	7	3	1 to 15	81.0
06-July-2002	0500	80	200.6	39.8	5	2	1 to 14	79.1
08-July-2002	0600	72	179.9	40.0	5	2	1 to 14	79.0
09-July-2002	2200	90	224.5	40.0	5	2	1 to 14	80.1
10-July-2002	0500	56	137.5	40.7	4	2	1 to 13	77.7
11-July-2002	2200	110	304.6	36.1	7	3	1 to 15	82.0
12-July-2002	0500	65	160.1	40.5	4	2	1 to 15	78.3
13-July-2002	2200	110	297.3	36.9	.	.	1 to 15	81.9
14-July-2002	0400	90	227.2	39.6	.	.	1 to 15	80.5
15-July-2002	2300	108	281.9	38.8	.	.	1 to 14	81.7
16-July-2002	0500	56	150.0	37.3	.	.	1 to 13	78.1
17-July-2002	2200	110	279.9	39.2	.	.	1 to 15	82.0
18-July-2002	0500	90	227.2	39.6	.	.	1 to 15	80.7
19-July-2002	2200	106	282.8	37.4	.	.	1 to 15	81.2
20-July-2002	0500	68	175.8	38.6	.	.	1 to 14	78.5
21-July-2002	2300	100	267.6	37.2	.	.	1 to 15	80.2
22-July-2002	0500	82	207.4	39.6	.	.	1 to 15	79.3
Mean		95	235.4	40.4				80.3

Appendix 3. Fork lengths and weights of yearling Chinook salmon released at spill bay 4, during spring 2002.

Release Date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/01/02	0200	20	152.6	10.1	138-170	33.7	6.7	25.3-47.2
5/03/02	1000	20	147.2	9.2	126-162	29.3	4.8	19.1-37.5
5/05/02	0200	20	147.4	15.6	114-176	31.7	10.9	14.1-56.6
5/07/02	2200	20	148.4	14.1	128-174	31.1	9.0	19.1-49.5
5/09/02	0800	19	146.8	13.7	125-171	30.0	8.5	18.7-46.7
5/11/02	2200	20	139.2	8.0	124-152	24.2	4.1	18.2-33.3
5/13/02	0900	20	151.1	17.4	130-200	34.5	14.4	20.4-81.6
5/15/02	2200	20	150.1	21.6	120-200	33.6	16.7	16.2-82.3
5/17/02	0500	18	141.3	10.2	122-167	26.3	5.5	18.4-40.2
5/19/02	2200	18	152.0	18.7	123-190	32.6	12.7	14.2-62.3
5/21/02	0500	20	154.6	20.2	125-185	35.6	14.5	17.9-57.7
5/23/02	2200	20	143.7	14.4	120-179	29.2	9.4	15.4-54.5
5/25/02	0500	19	147.7	19.7	125-190	30.4	12.9	17.8-59.5
5/27/02	2200	20	150.8	14.7	137-189	31.6	10.8	22.6-59.0
5/29/02	0500	19	158.3	14.0	136-182	36.9	10.4	23.0-54.2
6/01/02	0500	19	153.4	20.1	132-213	34.8	17.2	22.0-95.9
Overall		313	149.0	16.0	114-213	31.6	11.5	14.1-95.9

Appendix 4. Fork lengths and weights of yearling Chinook salmon released at spill bay 9, during spring 2002.

Release Date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/01/02	0200	20	154.1	11.1	138-189	35.1	9.8	23.8-68.8
5/03/02	1000	20	149.7	16.4	120-187	32.9	11.8	15.3-63.2
5/05/02	0200	19	149.2	11.8	132-170	31.9	8.2	21.8-50.0
5/07/02	2200	20	147.4	12.1	126-172	29.8	7.0	17.4-42.7
5/09/02	0800	20	148.6	10.5	128-169	31.8	7.2	18.4-47.0
5/11/02	2200	20	143.2	13.3	128-173	27.3	9.5	17.1-51.3
5/13/02	0900	20	148.1	17.1	130-190	32.3	14.0	20.6-69.9
5/15/02	2200	20	151.0	18.1	127-190	33.4	13.4	17.9-66.5
5/17/02	0500	18	139.4	9.8	116-159	25.1	5.3	16.0-38.5
5/19/02	2200	20	146.6	14.1	128-180	29.0	9.3	17.1-54.0
5/21/02	0500	19	149.9	17.9	128-199	31.7	12.3	19.4-69.5
5/23/02	2200	20	147.1	18.7	122-188	31.7	13.2	17.8-64.4
5/25/02	0500	19	150.8	15.8	124-183	31.8	10.9	18.4-59.1
5/27/02	2200	20	160.8	9.2	144-176	37.6	7.0	26.1-49.3
5/29/02	0500	20	166.4	19.2	139-194	43.9	16.1	23.1-70.2
6/01/02	0500	20	149.7	13.4	132-183	31.1	8.7	20.8-56.4
Overall		315	150.1	15.6	116-199	32.3	11.2	15.3-70.2

Appendix 5. Fork lengths and weights of yearling Chinook salmon released at spill bay 13, during spring 2002.

Release Date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
5/01/02	0200	20	151.6	11.6	129-179	32.9	8.7	20.9-56.6
5/03/02	1000	18	151.0	13.1	120-172	32.6	7.9	15.4-48.0
5/05/02	0200	20	149.2	13.3	118-176	32.0	8.7	16.7-52.0
5/07/02	2200	20	148.6	10.5	129-162	30.6	6.3	18.3-39.6
5/09/02	0800	20	152.2	15.9	132-196	34.6	12.2	20.0-73.5
5/11/02	2200	20	139.6	7.5	124-152	24.4	4.3	16.2-33.2
5/13/02	0900	20	143.9	16.2	126-195	29.7	13.4	18.0-77.4
5/15/02	2200	21	149.4	17.2	125-187	32.5	12.8	17.6-64.8
5/17/02	0500	19	137.5	7.1	126-152	23.0	4.0	17.2-30.6
5/19/02	2200	20	146.8	19.5	119-197	31.0	14.8	16.1-77.9
5/21/02	0500	19	146.5	15.1	125-177	29.9	9.6	19.9-53.3
5/23/02	2200	19	149.6	22.2	125-193	33.2	14.8	18.3-62.6
5/25/02	0500	20	140.9	14.1	124-172	26.0	8.8	17.6-48.6
5/27/02	2200	20	155.0	14.2	132-180	34.3	10.0	19.3-52.5
5/29/02	0500	20	162.0	15.1	135-187	39.6	10.9	25.0-61.7
6/01/02	0500	19	143.6	10.9	124-164	26.6	6.1	16.8-40.0
Overall		315	148.0	15.3	118-197	30.8	10.7	15.4-77.9

Appendix 6. Fork lengths and weights of subyearling Chinook salmon released at spill bay 4, during summer 2002.

Release Date	Release time	N	Fork length (mm)			Weight (g)		
			Mean	SD	Range	Mean	SD	Range
7/02/02	2400	23	112.3	2.8	107-122	14.3	1.3	13.1-18.0
7/02/02	0500	21	113.9	4.0	110-124	14.9	2.2	13.1-21.9
7/03/02	2200	17	115.1	6.9	109-139	15.8	3.1	13.2-26.4
7/05/02	2200	25	116.4	7.2	111-146	16.4	4.0	13.0-32.6
7/06/02	0500	25	117.2	7.5	110-139	16.6	3.5	13.1-26.7
7/08/02	0600	24	117.7	6.3	110-130	16.7	2.9	13.1-21.6
7/09/02	2200	25	117.7	7.0	110-139	17.0	3.1	13.3-26.8
7/10/02	0500	25	118.9	9.1	110-149	17.8	4.6	13.0-34.7
7/11/02	2200	22	118.4	7.6	112-143	17.5	4.2	13.8-32.5
7/12/02	0500	25	117.3	5.9	110-133	16.8	3.1	13.2-25.9
7/13/02	2200	18	115.0	6.1	110-130	16.0	2.8	13.4-22.8
7/14/02	0400	23	119.3	8.5	111-139	18.2	4.3	13.7-28.0
7/15/02	2300	25	117.6	8.4	108-148	17.0	4.0	13.1-31.0
7/16/02	0500	25	113.3	3.3	109-124	14.7	1.5	13.1-19.4
7/17/02	2200	25	118.9	8.1	111-141	18.0	3.8	14.0-27.1
7/18/02	0500	25	119.2	7.2	110-136	17.8	3.1	13.4-24.7
7/19/02	2200	24	121.2	7.4	110-139	19.6	4.1	13.5-27.8
7/20/02	0500	22	127.8	12.2	110-157	22.2	6.9	13.5-42.4
7/21/02	2300	26	119.0	8.4	110-145	17.8	4.0	13.9-29.8
7/22/02	0500	25	124.6	10.5	110-152	20.5	6.1	13.4-40.8
Overall		470	118.1	8.2	107-157	17.3	4.2	13.0-42.4

Appendix 7. Fork lengths and weights of subyearling Chinook salmon released at spill bay 13, during summer 2002.

Release Date	Release time	N	Fork length (mm) Mean	SD	Range	Weight (g) Mean	SD	Range
7/02/02	2400	23	114.5	5.7	109-133	15.4	2.7	12.4-22.8
7/02/02	0500	21	114.1	2.7	110-119	15.0	1.2	13.5-18.6
7/03/02	2200	16	115.7	4.3	111-125	16.1	2.1	13.1-20.6
7/05/02	2200	24	113.6	4.2	110-130	14.8	1.8	13.0-21.0
7/06/02	0500	24	116.8	6.6	110-133	16.6	3.3	13.0-25.9
7/08/02	0600	25	116.1	6.8	109-131	16.3	3.4	13.1-25.2
7/09/02	2200	25	118.9	7.4	111-136	17.4	3.7	13.3-24.7
7/10/02	0500	00*	.	.	.	.	.	.
7/11/02	2200	18	119.1	7.3	112-143	18.2	4.0	14.3-30.2
7/12/02	0500	25	118.7	9.0	112-150	17.4	4.7	13.1-34.3
7/13/02	2200	18	118.1	6.8	111-136	16.9	2.8	13.8-23.2
7/14/02	0400	25	118.2	9.6	110-149	17.3	4.6	13.9-31.3
7/15/02	2300	25	117.2	7.7	110-137	16.8	3.8	13.6-27.7
7/16/02	0500	24	115.2	4.9	110-130	15.6	2.3	13.2-21.9
7/17/02	2200	25	119.5	7.7	110-139	17.9	3.5	13.8-28.1
7/18/02	0500	24	115.5	6.4	110-135	16.7	3.3	13.5-25.0
7/19/02	2200	25	122.7	9.5	110-147	19.1	4.6	12.8-32.9
7/20/02	0500	25	131.5	10.1	112-151	24.2	5.3	14.0-34.3
7/21/02	2300	25	120.5	8.3	110-143	18.4	4.1	13.8-29.4
7/22/02	0500	24	118.3	7.1	109-137	17.5	3.1	13.2-24.7
Overall		441	118.2	8.2	109-151	17.3	4.1	12.4-34.3

*23 fish were released through SB11, not included in analysis

Appendix 8. Summary of residence times (minutes) of radio-tagged yearling Chinook salmon detected by an aerial antenna array in the stilling basin of The Dalles Dam after being released through spill bay 4 (SB04), 9 (SB09), or 13 (SB13). N = sample size, 5% = 5^{th} percentile, 95% = 95^{th} percentile, CV = coefficient of variation, . = not calculable.

Release Site	Release Date	N	Mean	Median	5%	95%	Minimum	Maximum	Range	CV
SB04	01MAY2002	20	2.87	2.15	1.58	9.27	1.57	14.48	12.92	97.35
	03MAY2002	1	1.48	1.48	1.48	1.48	1.48	1.48	0.00	.
	07MAY2002	14	0.93	0.94	0.18	1.92	0.18	1.92	1.73	46.39
	09MAY2002	6	5.95	1.32	0.48	18.65	0.48	18.65	18.17	131.21
	11MAY2002	19	2.58	1.30	0.60	20.72	0.60	20.72	20.12	174.86
	13MAY2002	4	1.42	1.00	0.15	3.52	0.15	3.52	3.37	107.86
	15MAY2002	11	1.01	1.00	0.60	1.52	0.60	1.52	0.92	27.88
	17MAY2002	12	3.97	1.28	0.87	32.85	0.87	32.85	31.98	229.26
	19MAY2002	11	0.93	0.95	0.78	1.15	0.78	1.15	0.37	12.14
	21MAY2002	19	1.75	1.40	0.50	5.03	0.50	5.03	4.53	64.12
	23MAY2002	14	0.59	0.61	0.22	1.05	0.22	1.05	0.83	45.21
	25MAY2002	20	1.09	0.88	0.23	2.90	0.10	3.63	3.53	73.20
	27MAY2002	15	1.09	0.87	0.13	3.25	0.13	3.25	3.12	73.31
	29MAY2002	17	0.81	0.82	0.30	1.33	0.30	1.33	1.03	34.86
	01JUN2002	15	1.26	1.02	0.38	4.28	0.38	4.28	3.90	78.80
	Summary-SB04	198	1.73	1.05	.32	3.63	0.10	32.85	32.75	187.09
SB09	01MAY2002	20	1.88	1.70	1.08	4.47	0.88	6.05	5.17	57.11
	03MAY2002	1	0.05	0.05	0.05	0.05	0.05	0.05	0.00	.
	07MAY2002	10	1.15	1.13	0.65	1.63	0.65	1.63	0.98	28.68
	09MAY2002	10	2.44	1.38	0.40	13.52	0.40	13.52	13.12	161.22
	11MAY2002	20	1.83	1.22	0.41	7.23	0.13	12.17	12.03	136.30
	13MAY2002	3	1.24	1.58	0.17	1.98	0.17	1.98	1.82	76.71
	15MAY2002	15	5.01	0.60	0.15	65.17	0.15	65.17	65.02	332.59
	17MAY2002	14	1.05	0.75	0.58	4.85	0.58	4.85	4.27	105.61
	19MAY2002	20	1.23	1.05	0.53	2.67	0.42	2.92	2.50	50.43
	21MAY2002	18	1.27	1.15	0.58	2.03	0.58	2.03	1.45	35.20
	23MAY2002	16	0.80	0.84	0.33	1.23	0.33	1.23	0.90	35.76
	25MAY2002	17	0.83	0.80	0.57	1.12	0.57	1.12	0.55	20.25
	27MAY2002	19	1.05	1.05	0.43	1.98	0.43	1.98	1.55	40.90
	29MAY2002	20	0.90	0.82	0.46	1.70	0.43	2.18	1.75	41.32
	01JUN2002	17	0.94	0.93	0.13	1.83	0.13	1.83	1.70	44.89
	Summary-SB09	220	1.51	1.00	0.43	2.14	0.05	65.17	65.12	298.22
SB13	01MAY2002	20	5.24	4.68	2.63	9.41	2.37	10.08	7.72	38.62
	03MAY2002	1	13.02	13.02	13.02	13.02	13.02	13.02	0.00	.
	07MAY2002	20	4.68	1.84	0.98	19.99	0.93	23.92	22.98	127.32
	09MAY2002	8	4.64	1.36	0.72	21.28	0.72	21.28	20.57	156.53
	11MAY2002	20	2.29	1.73	1.05	8.20	1.00	13.37	12.37	115.99
	13MAY2002	8	1.49	0.99	0.60	4.40	0.60	4.40	3.80	83.85
	15MAY2002	19	5.69	2.32	0.67	64.22	0.67	64.22	63.55	250.19
	17MAY2002	18	2.78	2.00	0.67	14.38	0.67	14.38	13.72	115.69
	19MAY2002	17	2.17	1.65	0.88	6.93	0.88	6.93	6.05	81.84
	21MAY2002	18	1.76	1.25	0.63	8.08	0.63	8.08	7.45	98.27
	23MAY2002	14	2.39	1.63	0.65	7.98	0.65	7.98	7.33	95.09
	25MAY2002	19	1.42	1.37	0.80	2.13	0.80	2.13	1.33	23.70
	27MAY2002	18	1.55	1.46	0.80	2.55	0.80	2.55	1.75	34.28
	29MAY2002	20	1.28	1.26	0.63	2.01	0.62	2.03	1.42	29.04
	01JUN2002	18	1.66	1.44	1.03	3.02	1.03	3.02	1.98	35.32
	Summary-SB13	238	2.84	1.63	0.73	8.08	0.60	64.22	63.62	175.90

Appendix 9. Summary of residence times (minutes) of radio-tagged yearling Chinook salmon detected by an underwater antenna array in the stilling basin of The Dalles Dam after being released through spill bay 4 (SB04), 9 (SB09), or 13 (SB13). N = sample size, 5% = 5th percentile, 95% = 95th percentile, CV = coefficient of variation, . = not calculable.

Release Site	Release Date	N	Mean	Median	5%	95%	Minimum	Maximum	Range	CV
SB04	03MAY2002	7	0.99	0.92	0.57	2.13	0.57	2.13	1.57	53.46
	05MAY2002	4	1.18	0.91	0.60	2.30	0.60	2.30	1.70	64.68
	07MAY2002	1	2.80	2.80	2.80	2.80	2.80	2.80	0.00	.
	09MAY2002	1	0.50	0.50	0.50	0.50	0.50	0.50	0.00	.
	13MAY2002	2	1.08	1.08	0.90	1.27	0.90	1.27	0.37	23.93
	23MAY2002	1	0.42	0.42	0.42	0.42	0.42	0.42	0.00	.
	Summary-SB04	16	1.10	0.91	0.42	2.80	0.42	2.80	2.38	63.75
SB09	03MAY2002	1	0.45	0.45	0.45	0.45	0.45	0.45	0.00	.
	05MAY2002	2	1.16	1.16	0.92	1.40	0.92	1.40	0.48	29.51
	09MAY2002	1	1.23	1.23	1.23	1.23	1.23	1.23	0.00	.
	13MAY2002	1	0.75	0.75	0.75	0.75	0.75	0.75	0.00	.
	Summary-SB09	5	0.95	0.92	0.45	1.40	0.45	1.40	0.95	39.87
SB13	03MAY2002	3	1.19	0.87	0.68	2.03	0.68	2.03	1.35	61.31
	05MAY2002	2	0.95	0.95	0.88	1.02	0.88	1.02	0.13	9.92
	13MAY2002	1	1.10	1.10	1.10	1.10	1.10	1.10	0.00	.
	15MAY2002	1	1.27	1.27	1.27	1.27	1.27	1.27	0.00	.
	23MAY2002	1	0.95	0.95	0.95	0.95	0.95	0.95	0.00	.
	Summary-SB13	8	1.10	0.98	0.68	2.03	0.68	2.03	1.35	37.69

Appendix 10. Summary of residence times (minutes) of radio-tagged subyearling Chinook salmon detected by an aerial antenna array in the stilling basin of The Dalles Dam after being released through spill bay 4 (SB04) or 13 (SB13). N=sample size, 5%=5th percentile, 95%=95th percentile, CV=coefficient of variation, . = not calculable.

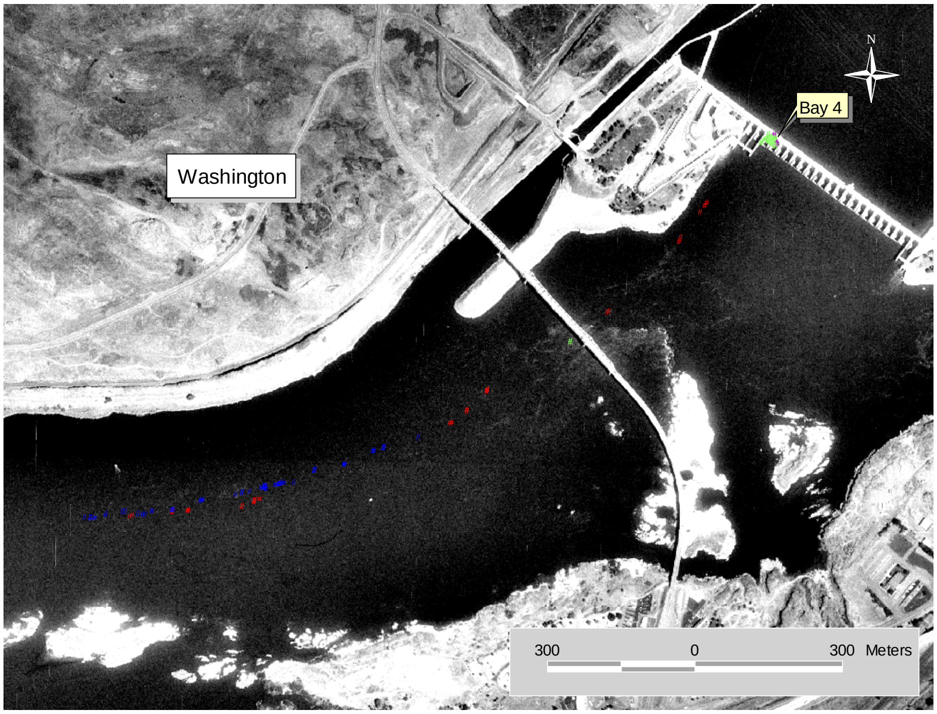
Release Site	Release Date	N	Mean	Median	5%	95%	Minimum	Maximum	Range	CV
SB04	02JUL2002	22	2.65	1.38	0.87	6.75	0.80	14.70	13.90	119.56
	02JUL2002	20	1.68	1.12	0.74	6.81	0.67	7.62	6.95	106.14
	03JUL2002	17	4.01	1.63	1.00	22.32	1.00	22.32	21.32	132.76
	05JUL2002	23	2.20	1.52	0.88	2.40	0.82	16.50	15.68	142.96
	06JUL2002	24	2.16	1.57	1.12	4.93	1.12	7.55	6.43	71.06
	08JUL2002	22	3.35	0.83	0.15	18.95	0.08	18.97	18.88	187.05
	09JUL2002	25	1.99	1.13	0.63	4.67	0.48	18.90	18.42	181.56
	10JUL2002	24	1.46	1.41	0.92	2.22	0.92	2.32	1.40	29.30
	11JUL2002	18	1.03	1.03	0.67	1.65	0.67	1.65	0.98	22.97
	12JUL2002	24	2.84	1.68	0.85	5.45	0.72	20.83	20.12	140.85
	13JUL2002	16	1.69	0.93	0.07	14.10	0.07	14.10	14.03	197.42
	14JUL2002	22	2.95	1.41	0.57	6.63	0.10	31.60	31.50	221.72
	15JUL2002	23	2.76	1.42	0.88	7.47	0.68	23.40	22.72	171.36
	16JUL2002	22	1.82	1.58	0.82	3.87	0.12	4.47	4.35	54.30
	17JUL2002	23	1.44	1.30	0.72	3.45	0.65	5.00	4.35	67.33
	18JUL2002	23	1.73	1.68	0.85	2.43	0.02	6.18	6.17	63.29
	19JUL2002	20	1.34	1.29	0.33	2.45	0.12	2.48	2.37	46.23
	20JUL2002	22	2.19	1.58	1.08	3.28	0.85	12.38	11.53	107.00
	21JUL2002	23	1.06	0.78	0.50	1.55	0.38	6.35	5.97	111.97
	22JUL2002	24	2.51	1.68	0.82	7.07	0.67	15.63	14.97	125.70
	Summary-SB04	437	2.14	1.37	0.57	6.63	0.02	31.60	31.58	154.12
SB13	02JUL2002	23	3.72	1.98	1.07	15.47	0.98	15.72	14.73	109.28
	02JUL2002	20	1.68	1.38	0.92	4.53	0.87	6.82	5.95	74.59
	03JUL2002	15	5.75	2.52	1.42	26.27	1.42	26.27	24.85	117.12
	05JUL2002	24	2.03	1.88	0.92	3.25	0.77	3.48	2.72	37.35
	06JUL2002	23	4.59	2.58	1.22	17.78	1.17	19.55	18.38	116.79
	08JUL2002	23	2.64	1.57	0.45	10.18	0.28	14.03	13.75	135.31
	09JUL2002	25	1.76	1.58	0.78	3.00	0.63	5.72	5.08	60.27
	10JUL2002	0*	.	.	.	.	.	.	.	.
	11JUL2002	18	1.50	1.42	0.53	4.43	0.53	4.43	3.90	58.22
	12JUL2002	24	5.56	2.75	0.77	22.08	0.08	22.37	22.28	111.49
	13JUL2002	18	1.73	1.33	0.75	7.55	0.75	7.55	6.80	94.50
	14JUL2002	25	3.70	1.75	0.98	15.23	0.67	21.38	20.72	143.44
	15JUL2002	25	5.13	1.98	1.27	21.52	1.20	51.70	50.50	204.53
	16JUL2002	24	2.98	2.39	1.18	4.35	1.08	17.03	15.95	103.51
	17JUL2002	25	1.41	1.27	0.72	3.00	0.70	3.70	3.00	47.51
	18JUL2002	23	3.04	1.80	1.03	7.10	1.03	20.47	19.43	133.70
	19JUL2002	24	2.83	1.47	0.90	5.17	0.80	23.80	23.00	162.61
	20JUL2002	24	3.14	1.58	0.55	5.73	0.55	36.53	35.98	229.18
	21JUL2002	23	1.66	1.42	0.78	3.38	0.78	3.97	3.18	48.92
	22JUL2002	24	4.06	2.08	0.22	16.52	0.22	20.83	20.62	126.26
	Summary-SB13	430	3.10	1.80	0.78	13.55	0.08	51.70	51.62	154.96

*23 fish were released through SB 11, not included in analysis

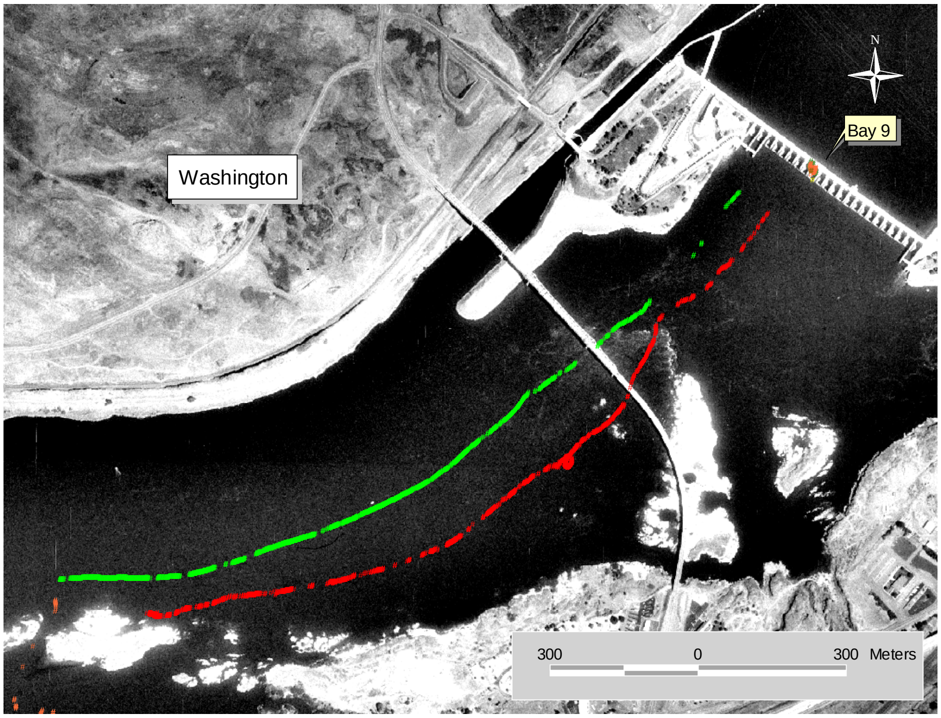
Appendix 11. Summary of residence times (minutes) of radio-tagged subyearling Chinook salmon detected by an underwater antenna array in the stilling basin of The Dalles Dam after being released through spill bay 4 (SB04) or 13 (SB13). N=sample size, 5%=5th percentile, 95%=95th percentile, CV=coefficient of variation, . = not calculable.

Release Site	Release Date	N	Mean	Median	5%	95%	Minimum	Maximum	Range	CV
SB04	02JUL2002	5	0.79	0.73	0.70	0.90	0.70	0.90	0.20	13.27
	03JUL2002	4	0.76	0.76	0.68	0.83	0.68	0.83	0.15	11.42
	05JUL2002	7	0.90	0.88	0.82	0.98	0.82	0.98	0.17	7.45
	06JUL2002	1	0.80	0.80	0.80	0.80	0.80	0.80	0.00	.
	08JUL2002	8	0.96	0.93	0.88	1.20	0.88	1.20	0.32	10.69
	09JUL2002	4	0.50	0.49	0.35	0.67	0.35	0.67	0.32	34.75
	12JUL2002	2	0.53	0.53	0.52	0.53	0.52	0.53	0.02	2.24
	13JUL2002	1	0.42	0.42	0.42	0.42	0.42	0.42	0.00	.
	14JUL2002	4	0.84	0.78	0.77	1.03	0.77	1.03	0.27	15.30
	15JUL2002	10	0.95	0.88	0.53	1.45	0.53	1.45	0.92	38.08
	16JUL2002	6	1.42	1.33	0.68	2.98	0.68	2.98	2.30	58.08
	17JUL2002	2	0.91	0.91	0.80	1.02	0.80	1.02	0.22	16.87
	18JUL2002	4	0.99	0.95	0.75	1.32	0.75	1.32	0.57	24.45
	19JUL2002	1	0.78	0.78	0.78	0.78	0.78	0.78	0.00	.
	22JUL2002	7	0.80	0.75	0.43	1.25	0.43	1.25	0.82	34.34
	Summary-SB04	66	0.89	0.83	0.43	1.38	0.35	2.98	2.63	41.01
SB13	03JUL2002	4	7.34	1.35	1.13	25.52	1.13	25.52	24.38	165.19
	08JUL2002	7	1.23	1.12	0.93	1.63	0.93	1.63	0.70	23.16
	09JUL2002	2	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.0
	11JUL2002	4	1.03	1.08	0.87	1.10	0.87	1.10	0.23	10.61
	12JUL2002	3	1.57	1.53	1.53	1.63	1.53	1.63	0.10	3.69
	13JUL2002	1	0.82	0.82	0.82	0.82	0.82	0.82	0.00	.
	14JUL2002	4	1.00	1.01	0.62	1.38	0.62	1.38	0.77	41.76
	15JUL2002	6	1.24	0.94	0.75	2.03	0.75	2.03	1.28	49.88
	17JUL2002	1	0.72	0.72	0.72	0.72	0.72	0.72	0.00	.
	18JUL2002	1	0.78	0.78	0.78	0.78	0.78	0.78	0.00	.
	19JUL2002	2	0.87	0.87	0.77	0.97	0.77	0.97	0.20	16.32
	20JUL2002	2	0.76	0.76	0.73	0.78	0.73	0.78	0.05	4.66
	22JUL2002	7	1.06	1.02	0.77	1.40	0.77	1.40	0.63	22.25
	Summary-SB13	44	1.66	1.05	0.72	2.03	0.62	25.52	24.90	222.05

Appendix 12. Depictions of GPS drogue paths at The Dalles Dam spillway from 5 May to 7 August 2002. Each graphic displays a deployment session. Table 7 reports averaged total spill and total discharge for each deployment session. Background photo does not represent study conditions. Drogues without GPS data are not depicted.

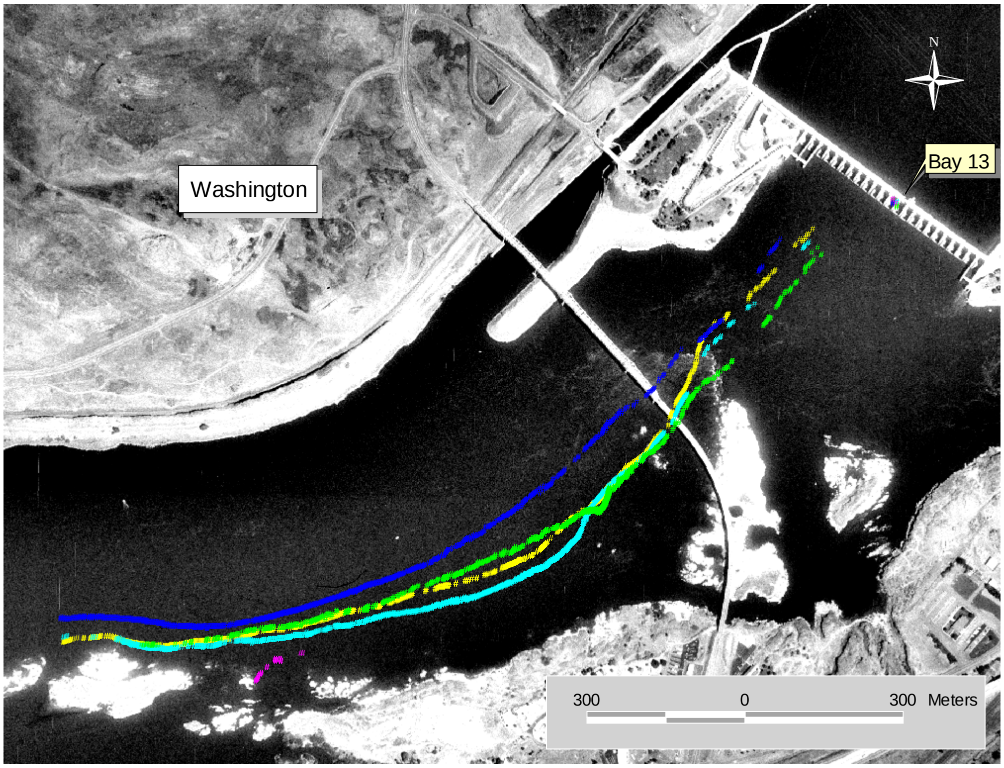


Deployment Date: 5-May-2002

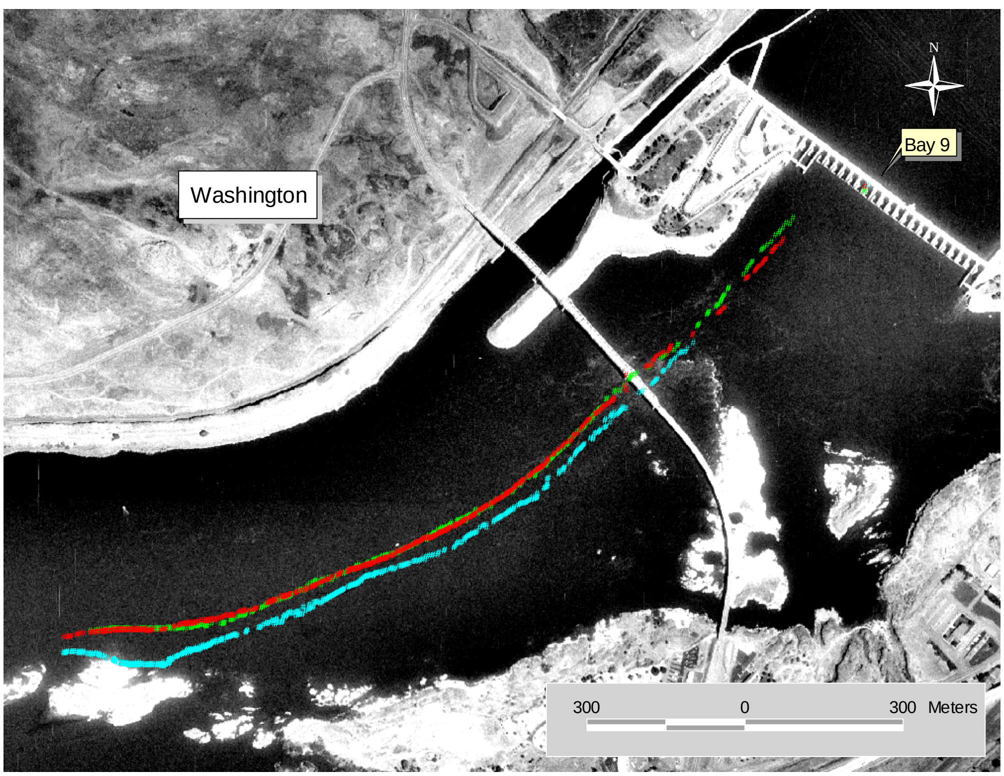


Deployment Date: 12-May-2002

Appendix 12 continued.

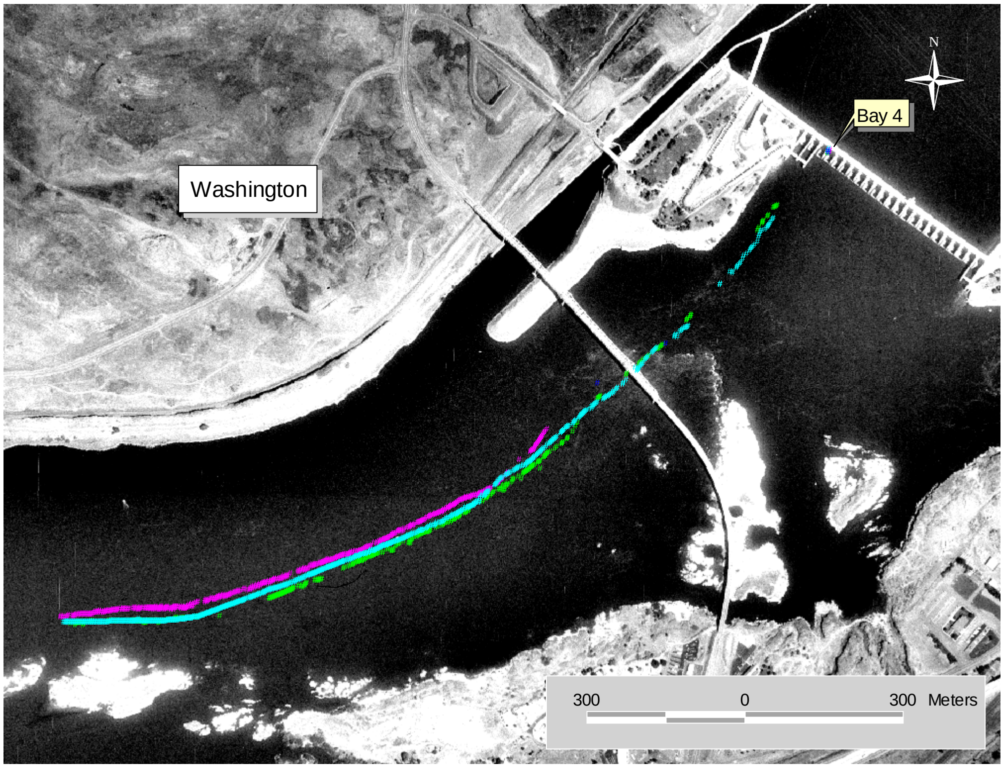


Deployment date: 17-May-2002

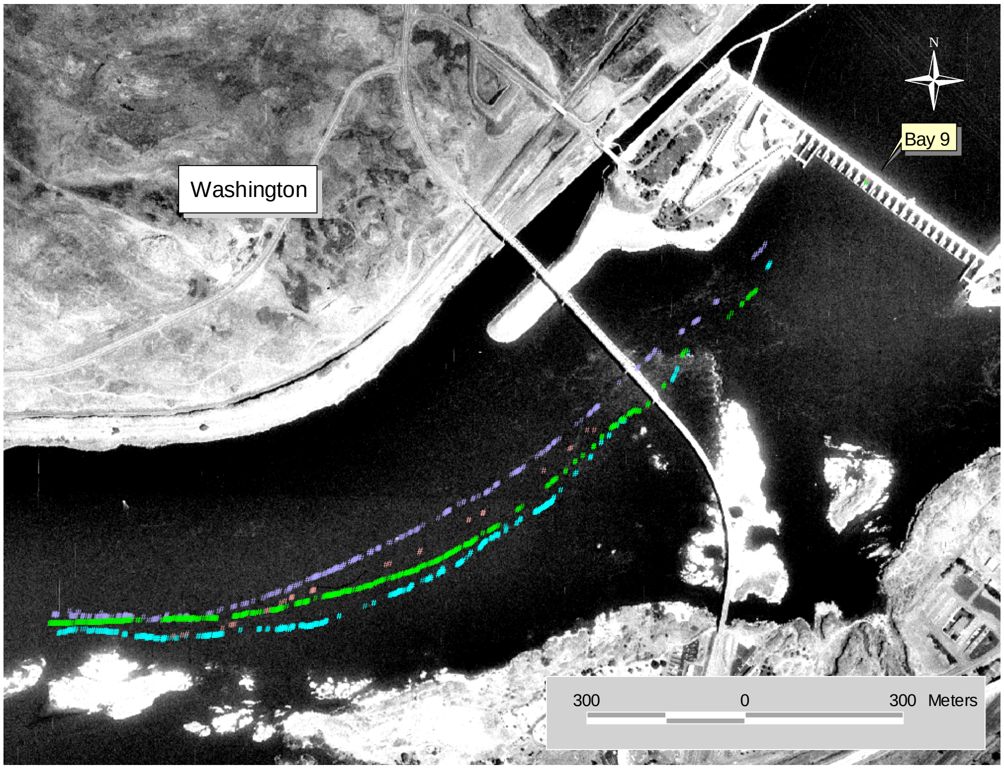


Deployment date: 22-May-2002

Appendix 12 continued.

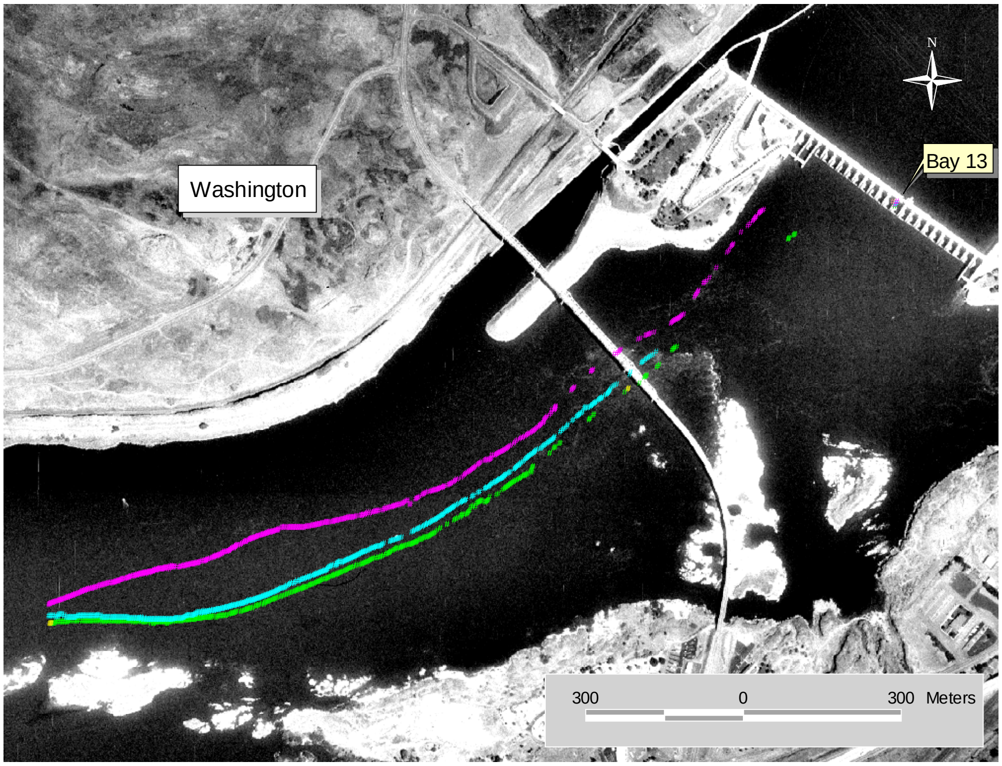


Deployment date: 25-May-2002

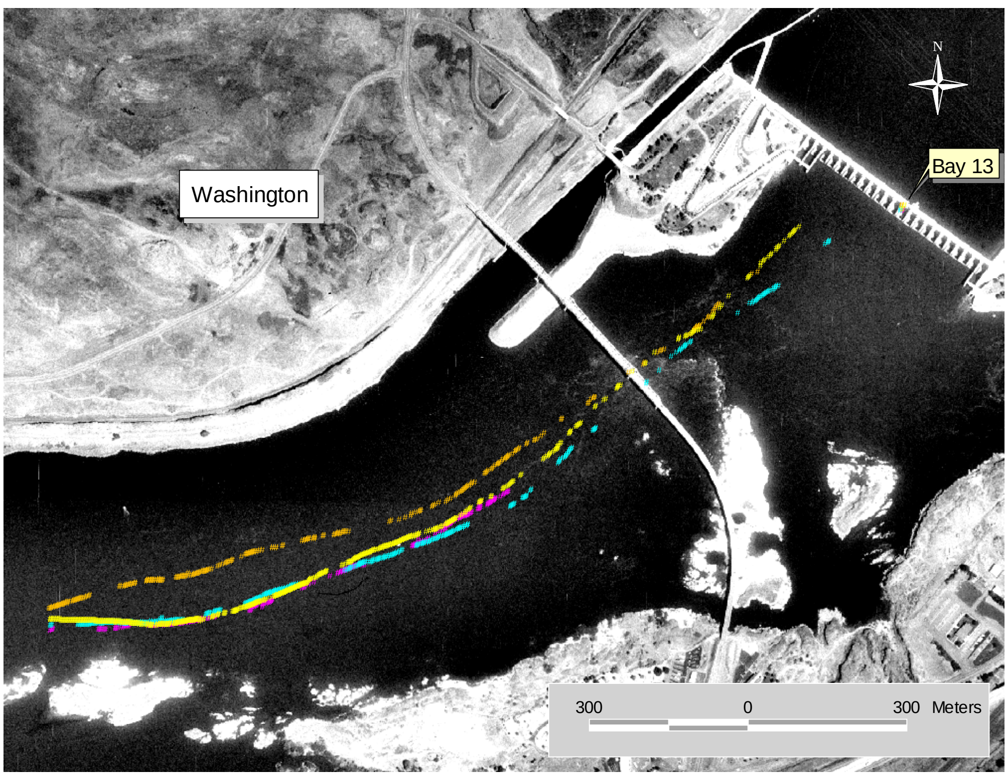


Deployment date: 26-May-2002

Appendix 12 continued.

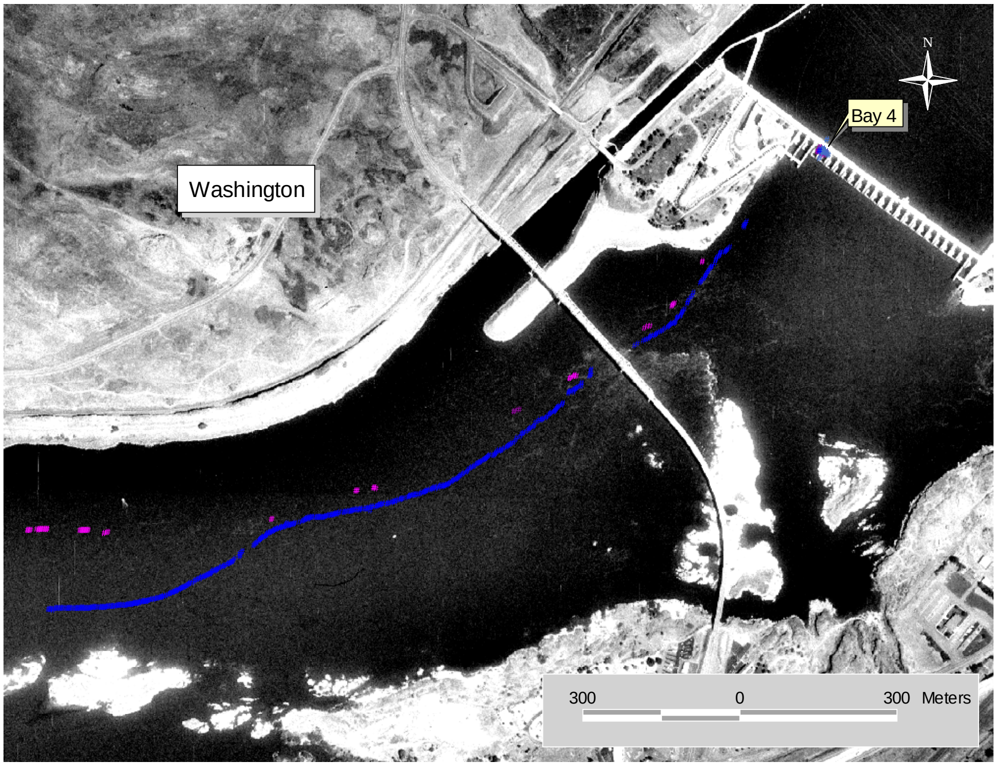


Deployment date: 31-May-2002

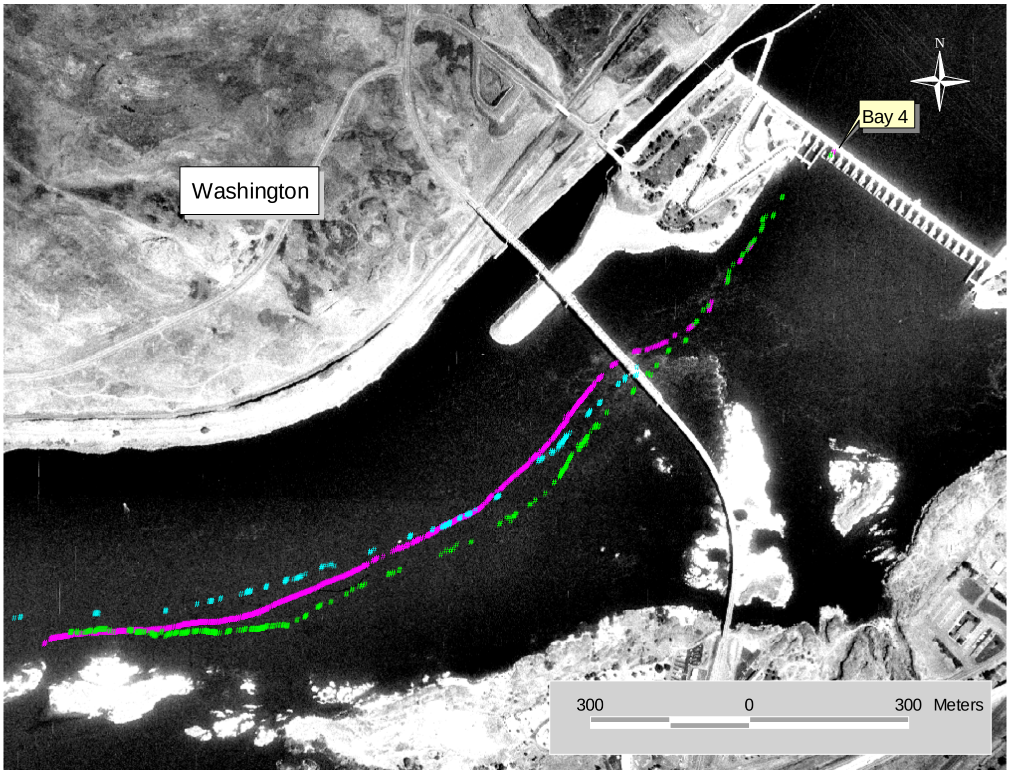


Deployment date: 3-June-2002

Appendix 12 continued.



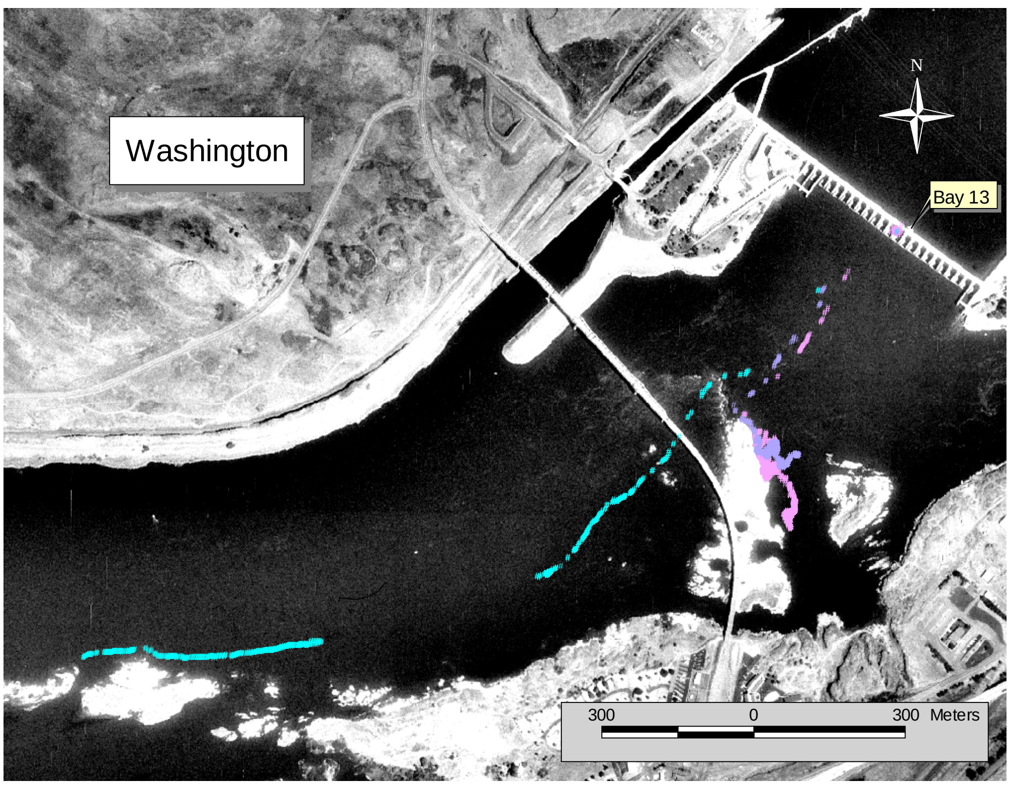
Deployment date: 4-June-2002



Deployment date: 6-July-2002

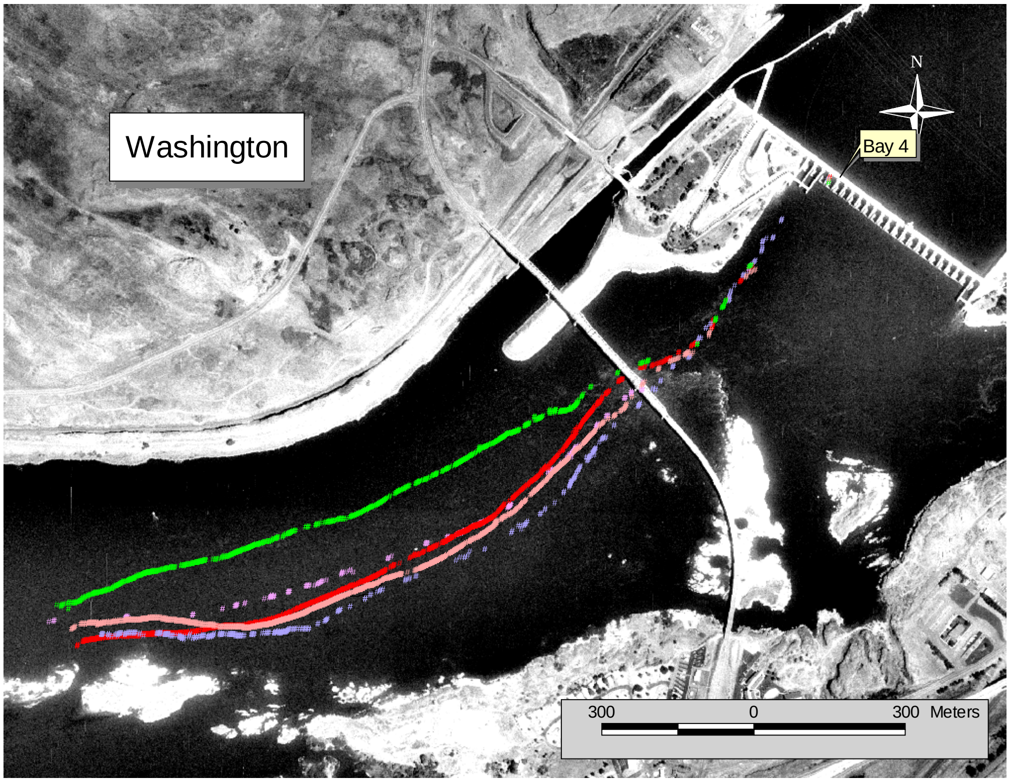
Appendix 12 continued.

Deployment date: 7-July-2002



Deployment date: 9-July-2002

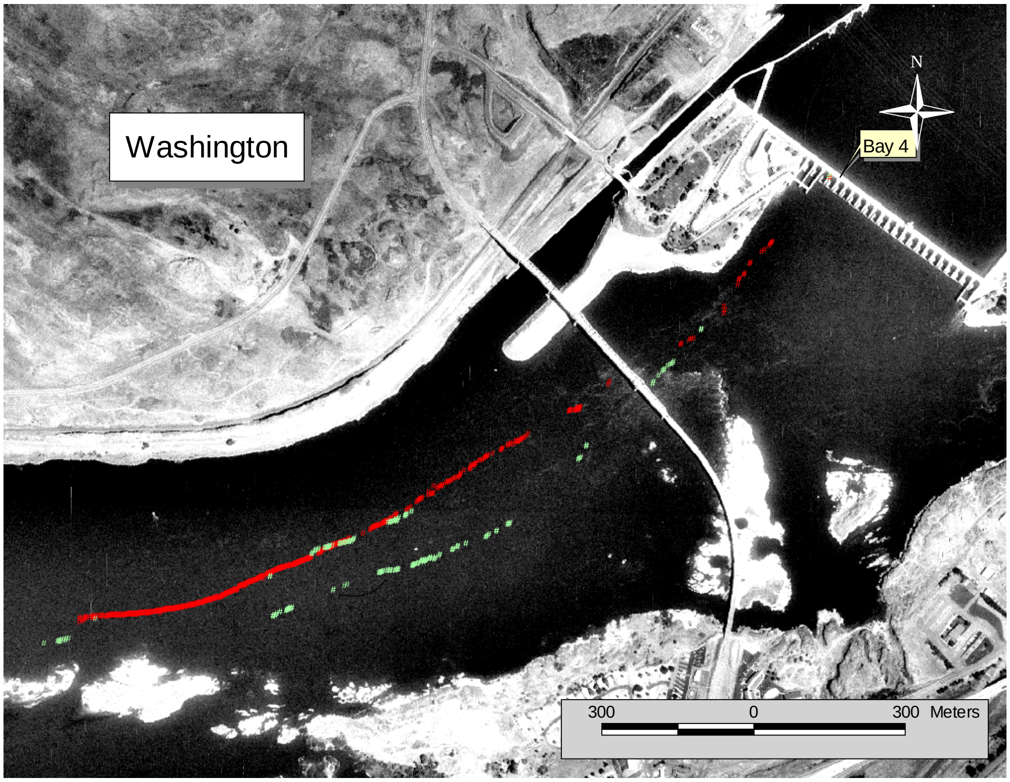
Appendix 12 continued.



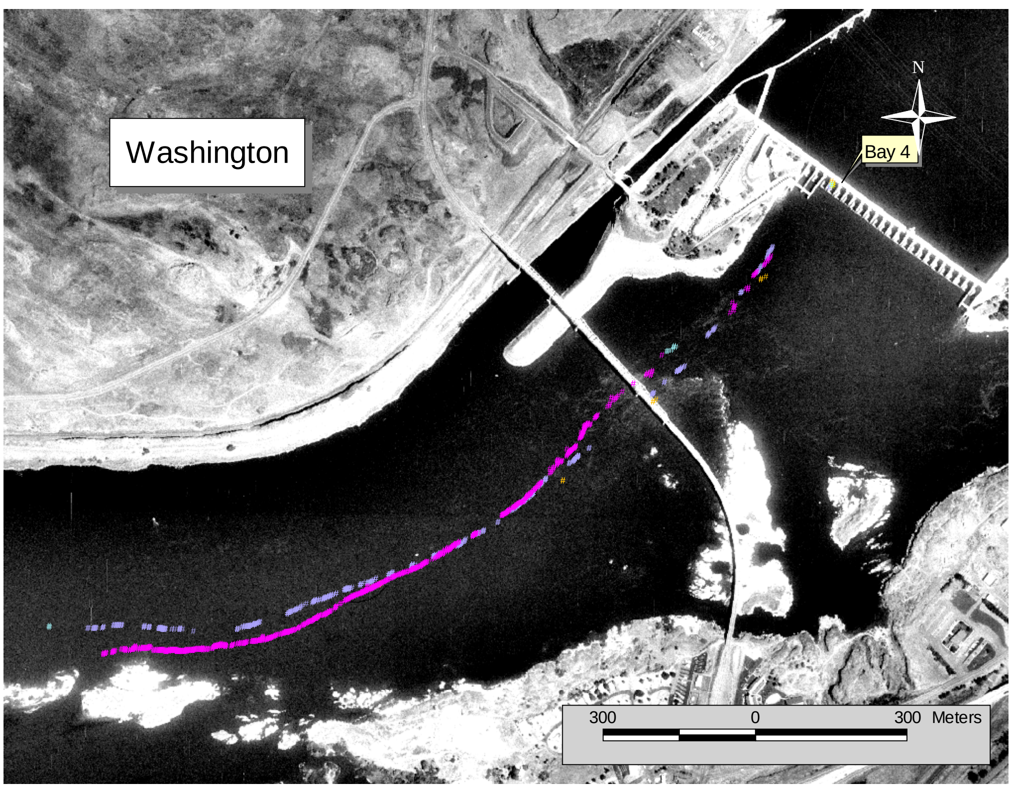
Deployment date: 11-July-2002

Deployment date: 15-July-2002

Appendix 12 continued.

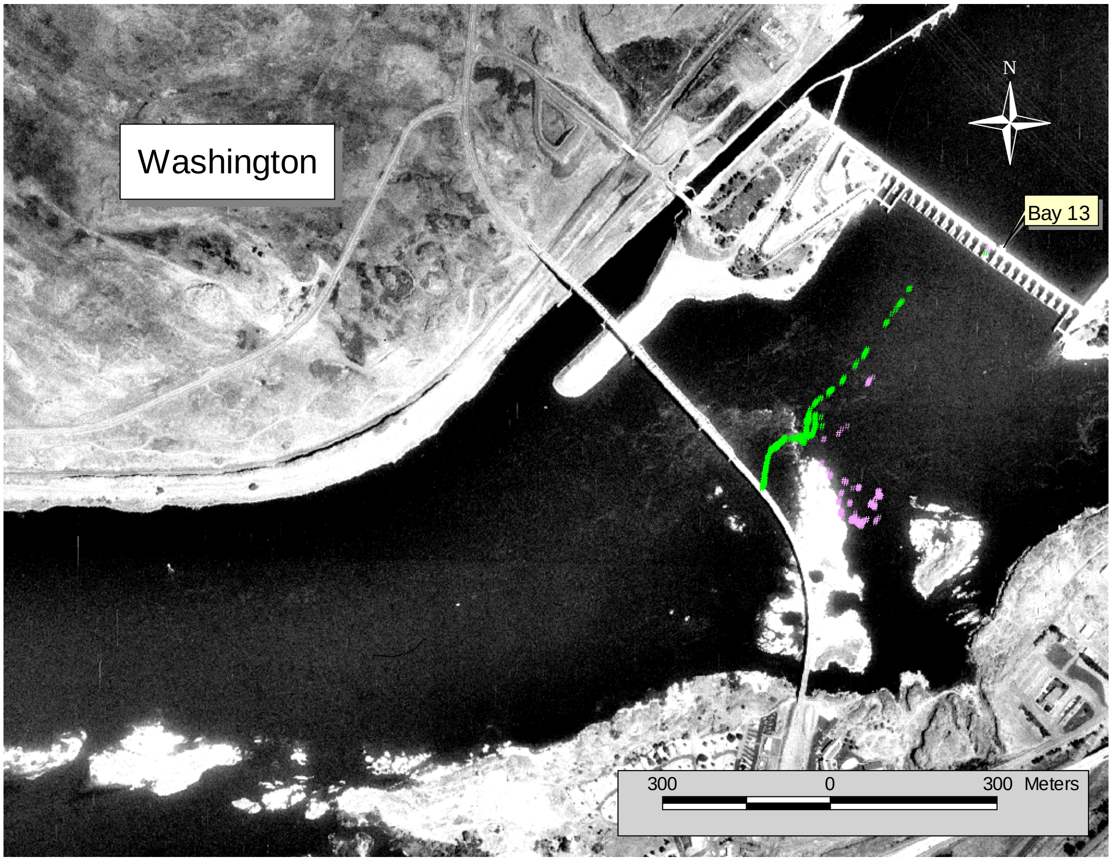


Deployment date: 17-July-2002



Deployment date: 23-July-2002

Appendix 12 continued.



Deployment date: 7-Aug-2002